MANITOBA CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

MAN
LA
CREDA

Canada

MANITOBA

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LOW ENERGY BERMED HOUSING

SHOAL LAKE — MANITOBA

MG-10341

14 (81-54)
1983

MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

1. SUMMARY

The Ewachewski residence was surveyed on three occasions. The first site visit was on July 15, 1981. At this time the excavation was complete and the piles and footings poured. The second site visit was on November 20, 1981. On this date the exterior walls and roof had been completed. The earth had been back-filled and windows installed. The front door had not been installed. The third site visit was made over a year later, on December 13, 1982. All site visits were conducted in the presence of the owner/builder. The construction features and techniques were pointed out by the owner, who paid particular attention to the air/vapour barrier, insulation, orientation and aesthetics.

The unique construction features of this home are summarized as follows:

.1 Earth sheltering over the majority of exterior walls.

.2 All windows are triple glazed.

.3 Insulation values far exceed today's standard.

.4 Entrances are protected from direct exposure to the outdoors.

.5 All windows have a southern exposure.

.6 Well sealed air/vapour barrier.

.7 Heat retaining atrium.

.8 Built-in provision for an active solar system.

Construction of the house began in early July of 1981, and at the time of this report is not yet completed. Items requiring completion are interior partitions and wall finish, plumbing, front entry and fixtures.

During the last site visit an air leakage test was performed using an infiltrometer (Appendix B).

The major objectives of the builder were as follows:

.1 To provide adequate comfortable living space with short term additional cost but long range economic payback as a result of energy conservation.

.2 To make use of Manitoba Hydro electric power as a major energy source with supplementing or complimenting solar and wood heat.

.3 To make full and efficient use of energy by employing conservation techniques, including earth berms, maximum insulation, heat retaining atrium, and a wood burning heat circulating fireplace or stove.

.4 To increase public acceptance of underground or semi-underground accommodation by demonstrating that comfortable conditions (temperature, humidity and lighting) can be achieved.

.5 To utilize pressure treated wood for the construction of underground earth retaining walls.

.6 To attract greater public attention to the need for alternate energy sources and to the new or revised technologies to be considered in building and construction.

It is unfortunate that one of the major objectives of the owner, which was to use a pressure treated wood underground wall, was not met. In future home building this technique should still be carefully considered in terms of life cycle cost compared to conventional concrete basements.

It is our opinion that by completion of the project the listed objectives will be fulfilled (with the above exception), assuming the public and other builders are made aware of the project.

1. Résumé

La résidence des Ewachewski fut examinée à trois reprises. On visita l'endroit pour la première fois le 15 juillet 1981. L'excavation ainsi que la construction des piliers et assises étaient alors terminées. Le 20 novembre 1981, l'endroit fut visité pour la deuxième fois. Les murs extérieurs et le toit étaient déjà construits à ce moment-là. On avait comblé avec de la terre et les fenêtres avaient été installées. La porte d'entrée n'était pas encore posée. Le 13 décembre 1982 - plus d'un an après - on visita l'endroit pour la troisième fois. Ces trois visites eurent lieu en présence du propriétaire-entrepreneur. Les caractéristiques de la maison furent décrites par le propriétaire qui fit valoir le pare-air/vapeur, l'isolation, l'orientation et les qualités esthétiques.

Les caractères distinctifs de cette maison sont résumés comme suit:

.1 La terre couvre la plupart des murs extérieurs.

.2 Toutes les fenêtres sont triples.

.3. L'isolation est supérieure à la normale.

.4 Les entrées ne sont pas exposées directement à l'air extérieur.

.5 Toutes les fenêtres font face au sud.

.6 Le pare-air/vapeur est bien hermétique.

.7 Il y a une verrière de toiture pour conserver la chaleur.

.8 La maison est construite pour le chaufface solaire actif.

C'est au début de juillet 1981 que fut commencée la construction de la maison qui n'est pas encore finie au moment où nous faisons ce rapport. Il reste encore à poser les cloisons intérieures et à en faire la finition, à installer la tuyauterie, à constuire l'entrée principale et à mettre toutes les installations.

Au cours de la dernière visite, on vérifia l'infiltration d'air au moyen d'un infiltromètre (Appendice B)

Les objectifs essentiels de l'entrepreneur étaient les suivants:

.1 Assurer la construction d'une résidence confortable avec des débours qui seront plus élevés pour commencer mais qui, grâce à la conservation de l'énergie, permettront à la longue des économies appréciables.

.2 Se servir du courant électrique d'Hydro-Manitoba comme source principale d'énergie avec chauffage supplémentaire ou complémentaire à l'énergie solaire et au bois.

.3 Utiliser l'énergie intégralement et efficacement grâce aux techniques de conservation comprenant: la construction semi-souterraine, l'isolation maximale, une verrière de toiture pour conserver la chaleur et une cheminée ou un poêle à bois à chaleur rayonnante.

.4 Encourager le public à accepter les résidences souterraines ou semi-souterraines en prouvant qu'elles peuvent être confortables (du point de vue de la température, de l'humidité et de l'éclairage).

.5 Construire une fondation en bois traité sous pression capable de retenir la terre.

.6 Faire de plus gros efforts pour attirer l'attention du grand public sur la nécessité de trouver des sources d'énergie de remplacement et sur les technologies nouvelles ou révisées de construction.

Il est regrettable que le propriétaire n'ait pu atteindre l'un de ses objectifs essentiels - lequel consistait à construire une fondation en bois traité sous pression. A l'avenir, il faudrait envisager sérieusement cette technique en tenant compte du coût réparti sur la durée cyclique d'utilisation par rapport aux sous-sols ordinaires en béton.

Si le public et les autres entrepreneurs sont tenus au courant du projet, nous estimons que tous les objectifs ci-dessus seront atteints à l'exception du dernier.

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2. SCOPE OF WORK AND BUILDING LOCATION

.1 Scope of Work

Our contract was to evaluate the construction techniques used in the Ewachewski Residence in Shoal Lake.

Our efforts were to concentrate on features that may make this residence unique when compared with conventional construction standards, as it relates to energy conservation. These areas include wall construction, insulation levels, roof trusses, air tightness levels and general construction techniques.

Specifically our evaluation was to consist of:

.1 Visiting the site and discussing building features with the Owner.

.2 Obtaining all available literature on this building from the Owner.

.3 Evaluation of building construction based on information 1. and 2.

.4 Preparation of final report, consisting of the following:

.1 The results of our monitoring, observations and evaluation.

.2 Comparative data for this home and other energy efficient homes being built at present.

.3 As a result of .1 and .2, our opinion, (with necessary qualifying information) as to whether or not the unique features of this building can be effectively utilized in Manitoba's housing industry.

.2 Location and Map

Shoal Lake is located approximately 170 miles (275 km) north west of Winnipeg on PTH #16. Fig. 1 shows the location of the Ewachewski residence in relationship to the town of Shoal Lake.

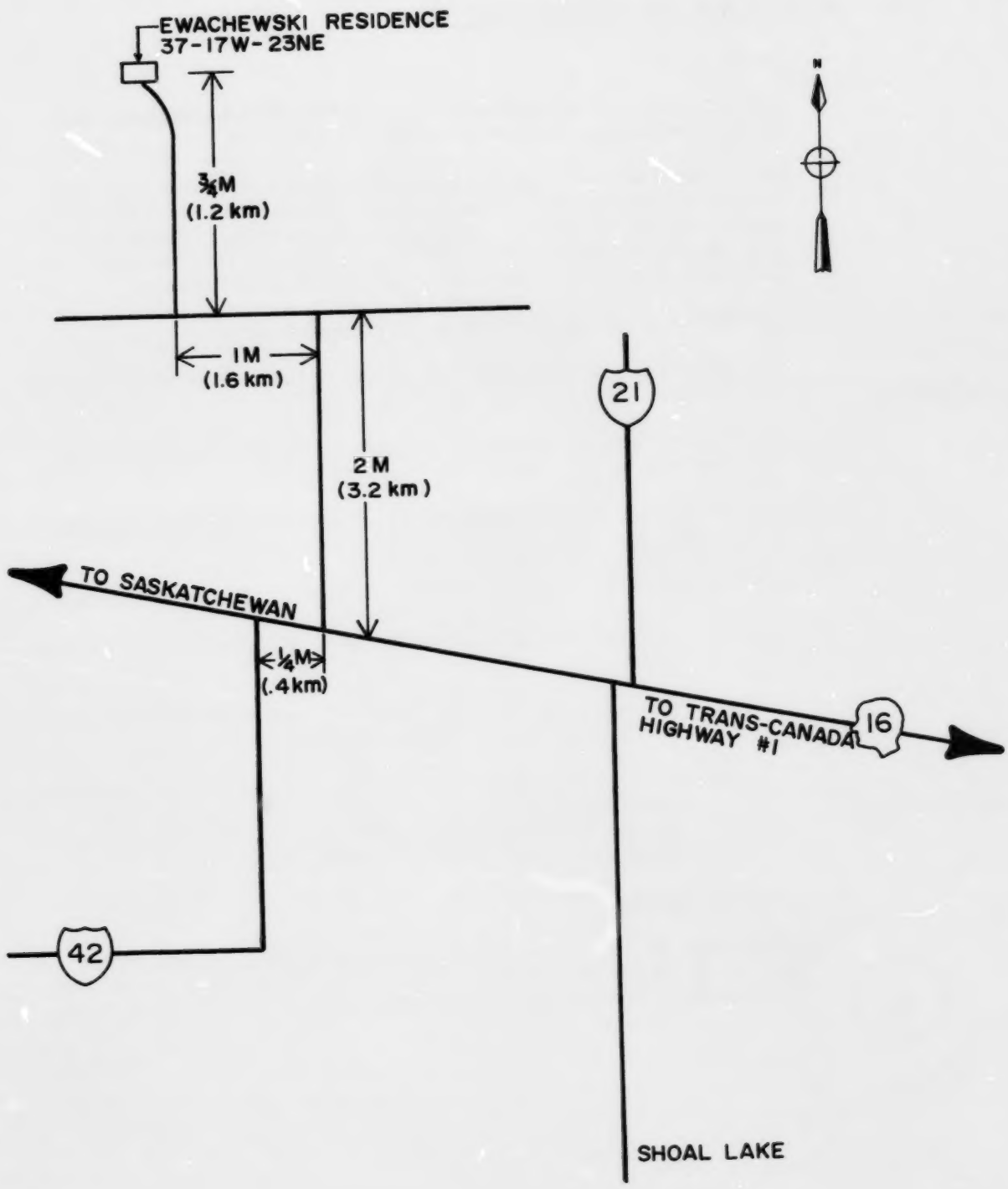

EWACHEWSKI RESIDENCE
37-17W-23NE
¾M
(1.2 km)
1M
(1.6 km)
2 M
(3.2 km)
21
TO SASKATCHEWAN
¼M
(.4km)
TO TRANS-CANADA
HIGHWAY #1
16
42
SHOAL LAKE

FIGURE 1

3. BUILDING DESCRIPTION

.1 General

The Ewachewski residence is located approximately 7 km north of Shoal Lake, Manitoba. Situated on a 2 hectare lot, the low energy home is built into the side of a hill with only the south wall exposed directly to the outdoors. In addition to being an earth sheltered home, the Owners have designed into their single level plans features that are both unique and functional in terms of energy conservation. Refer to Floor Plan - Appendix G.

.2 Building Areas

Component	Area (m^2)
Ceiling	268
Walls (net exposed)	57
Walls (net below grade)	162
Doors	3.3
Windows: South only	23.7
Crawlspace floor	268
Building volume	817

.3 Windows

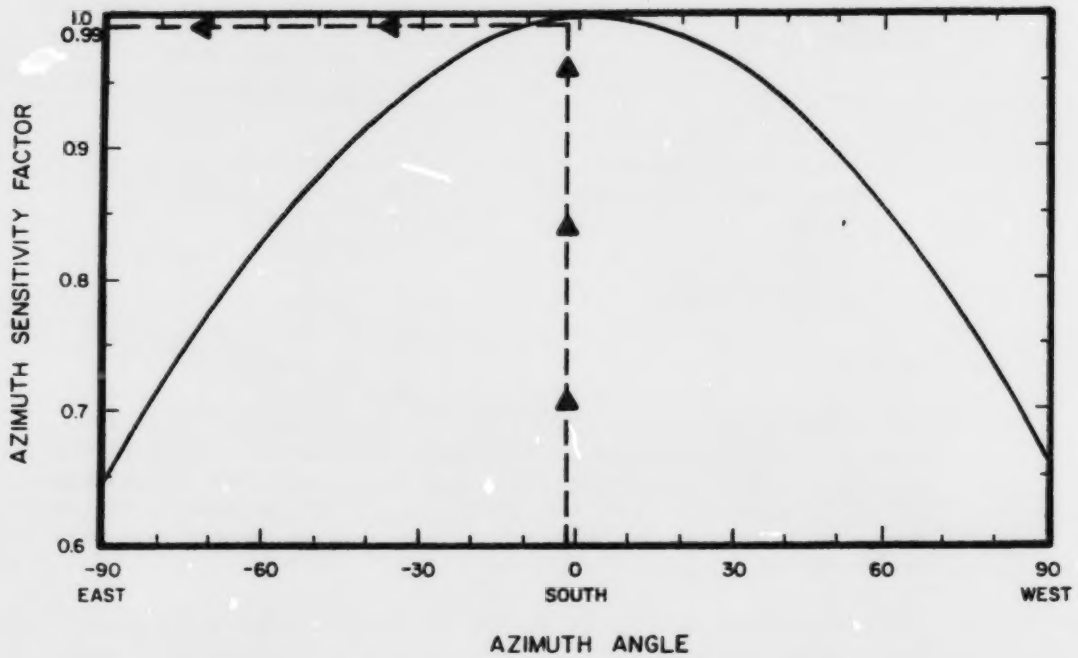
All windows are sealed triple glazed units manufactured by Bogardus Wilson Limited of Winnipeg. Depressurization of the home by the infiltrometer indicated that there was air leakage by the window unit, but the installation of the window was well done, as indicated by the lack of air leakage around the perimeter of the window casings.

The entire window area of 23.7m^2 is south facing and constitutes approximately 45% of the entire south facing wall area.

In Appendix D: Site Plan, window locations as well as the deviation from south are illustrated. This deviation is very minimal and affects the thermal performance of the windows only slightly as can be see in Figure 2.

.4 Roof Trusses

The type of roof trusses used are now common in low energy housing. These trusses are commercially manufactured and said to have a 'raised heel' (Figure 3) which allows the attic insulation to be laid to the required thickness right to the exterior of the perimeter wall. In this case glassfibre insulation was used and installed to a level of an R-60 (RSI 10.6) value.



Reduction in thermal performance for
azimuth angles deviating from true south (0°).

FIGURE 2

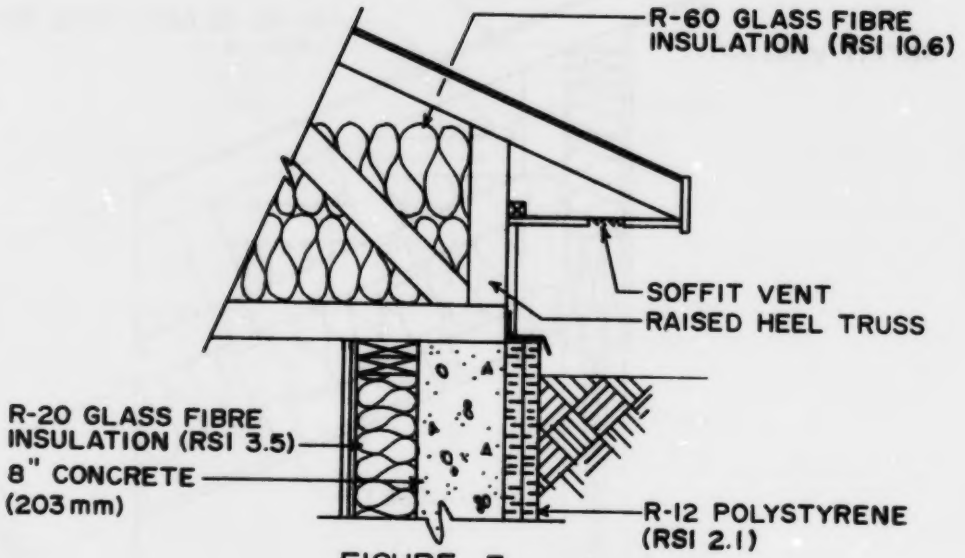


FIGURE 3

A flat truss is utilized over the atrium to form a cathedral ceiling sloping down from the south.

These trusses were designed to be 20" (508mm) in depth, but when received from the manufacturer were found to be only 16" (406mm) in depth. The builder then added 11" (280mm) to the depth by fastening additional 2 x 4 to the truss with 7" (178mm) spacers and gusset plates as shown in Figure 4. This allowed a total of R-80 (RSI 14.1) glassfibre insulation to be installed and still left a 5" (127mm) air space between the insulation and the under side of the roof sheathing.

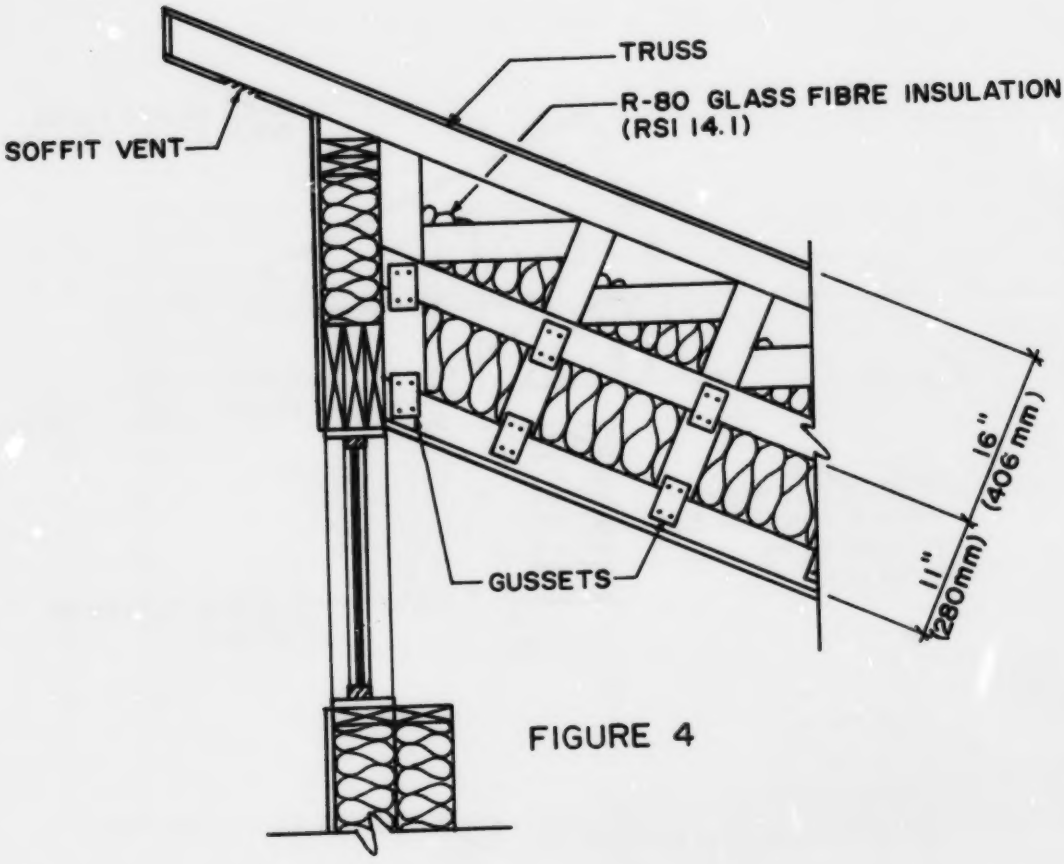


FIGURE 4

.5 Wall Framing

Two types of wall construction were used in the Ewachewski residence, one for the bermed portion and one for the exposed wall.

The exposed walls, south and west, employ the conventional type double wall as illustrated in Figure 5:

> Two - 2 x 4 framed walls with a 5" (125mm) space between them. This provides space for two R-12 (RSI 2.1) and one R-20 (RSI 3.5) glass fibre batts for a total R-Value of 44 (RSI 7.7) for the exposed walls.

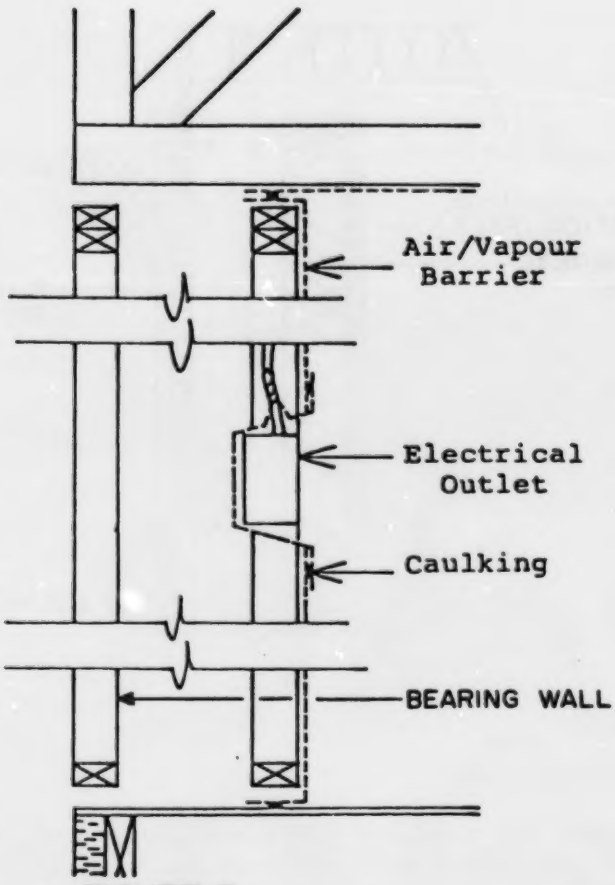


FIGURE 5

DOUBLE-WALL

(AIR/VAPOUR BARRIER ON INTERIOR OF INTERIOR WALL)

The below grade walls, north west and east, are 8" (200mm) reinforced concrete. The north and east walls are framed with 2 x 6's and insulated with R-20 (RSI 3.5) glass fibre batts from the interior (See Figure 6). The walls have then been additionally insulated with 3" (75mm) of expanded polystyrene, providing an extra R-12 (RSI 2.1) insulation value.

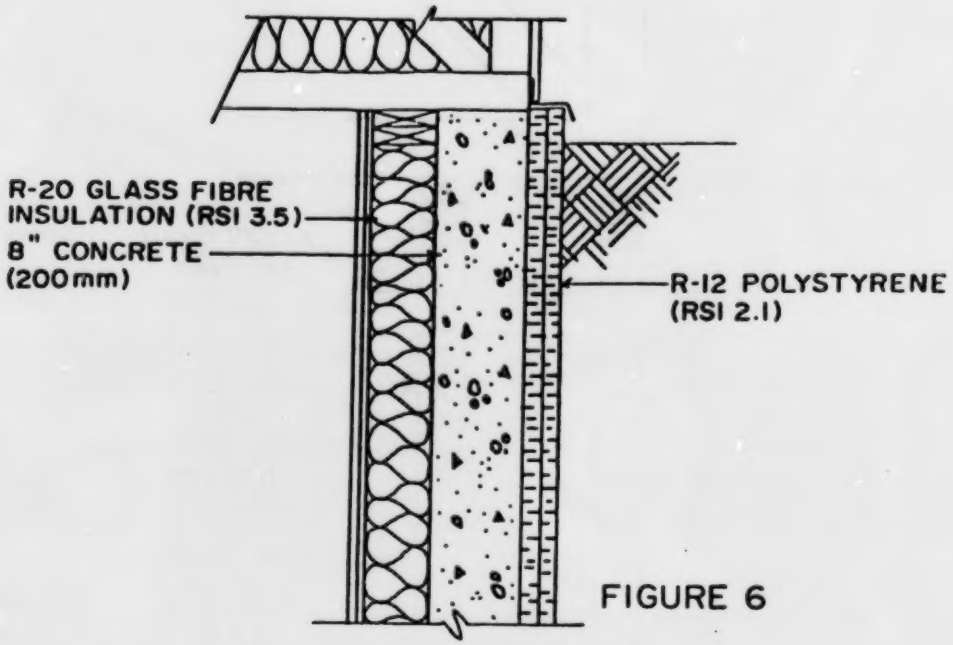


FIGURE 6

.6 Attic Ventilation

The reason for providing sufficient attic ventilation is to prevent the occurence of condensation/frost in the winter and heat build-up in the summer. Frost occurs in the attic only because of warm moist air leaking into the attic and then condensing and freezing if not expelled by ventilation. The Ewachewski residence utilizes continuous soffit venting along the front and rear of the house, as well as under the eaves of the shed roof over the atrium.

.7 Floor Joist/Foundation Wall Intersection

Because of the two different types of wall construction the intersection with the foundation and floor joists is unique to each.

The exterior wall for the below grade portion of the house is continuous in height from the footing to the top plate (approximately 10' or 3050mm). This provides a wall for the crawlspace as well as the living space, see Figure 7. The floor joists are then set upon a continuous pony wall which sits on the same footing as the concrete wall.

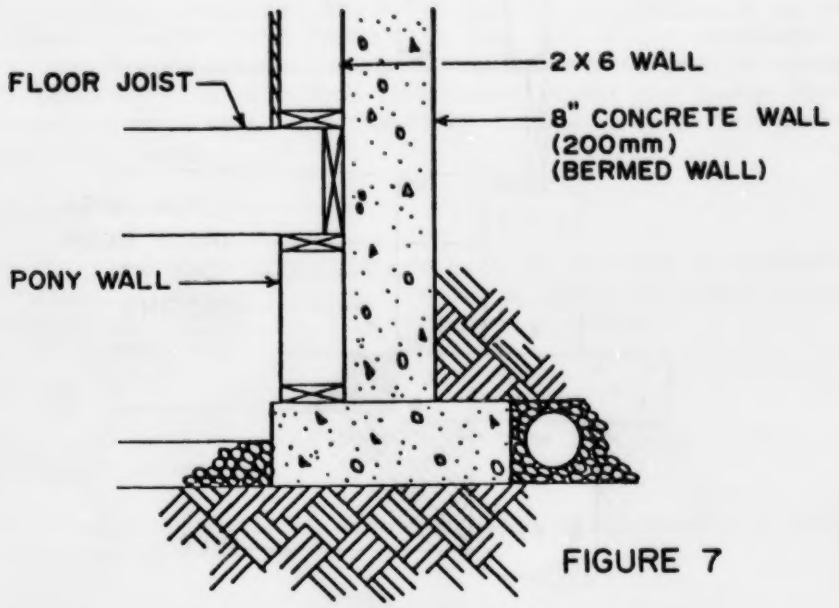


FIGURE 7

The exposed double wall portion of the house rests atop a 9" (225mm) concrete grade beam. The floor joists are fastened to a continuous sill plate anchored to the foundation (see Figure 8). A pony wall between the footing and the underside of the floor joists provides a framing for the glass fibre insulation.

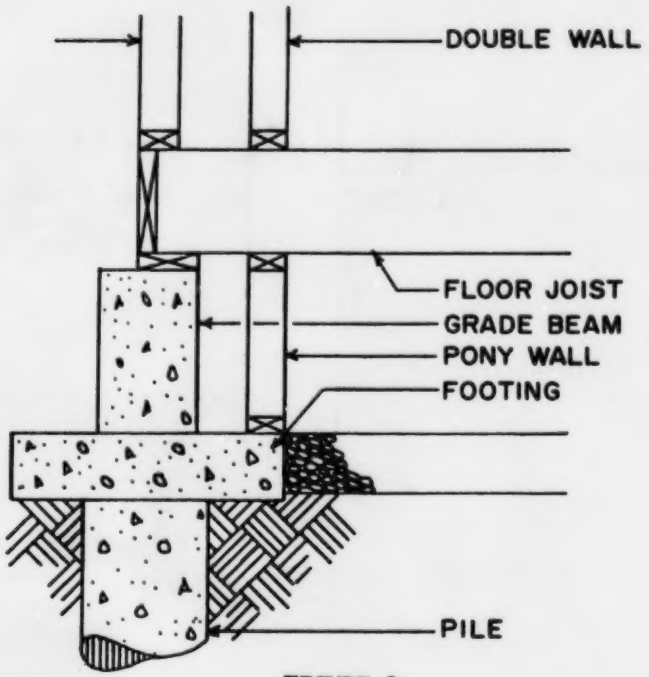


FIGURE 8

.8 Crawlspace

The crawlspace is approximately 2' (610mm) in height around the perimeter as illustrated in Figures 7 and 8, and is considered a heated crawlspace. All plumbing for domestic water use is installed in the crawlspace. The crawlspace floor is a made up of compacted gravel covered with 6 Mil polyethylene, but is not insulated.

.9 Earth Sheltering

The earth sheltered wall construction and landscaping in the immediate vicinity of the house are integral parts of the architectural design, as well as being functional. The majority of the outside wall surface area is sheltered with earth, then landscaped. This effectively reduces the temperature differential throughout the year, which in turn reduces the energy requirements for heating and cooling. The earth also provides protection from prevailing winds and precipitation, and minimizes exterior maintenance requirements for the home.

.10 Utilities

The property has its own water supply and septic field. Electricity is provided by Manitoba Hydro.

.11 Entrances

The Ewachewski home has 2 exterior door locations, both of which utilize steel insulated doors for maximum insulation in an entry system. An additional feature is that both entry locations are 'double protected' in one way or another to provide minimum air leakage. The rear door is located inside the garage for protection from wind, and the front door will open into an 'air lock' type foyer.

.12 Lighting

The majority of lighting for the home is provided by a mixture of natural lighting (through the large amount of south facing windows) and wall mounted incandescent lighting.

.13 Heating

There will be 3 types of heating systems installed in the Ewachewski house.

The primary system is an electric baseboard type with individual room control.

The first of the secondary systems is a wood stove with its own fresh air intake. The stove will be located in the south-east corner of the house.

The third system, to be installed in the future, is an active solar system with the heating medium circulated through the concrete slab floor of the atrium.

.14 Ventilation

As can be seen from Table 2, Appendix C, the Ewachewski residence is a relatively tight house, i.e. it has a very low air change rate. Because of this the Ewachewski's would not experience dryness in their home common during Manitoba winters. This is because tight sealing does not permit cold, dry winter air to infiltrate into the house. It is probable that the home may be too humid and stuffy. An air-to-air heat exchanger is a method of replacing this humid, stuffy air with fresh dry out-door air while recovering a good portion of the sensible and latent heat from the exhaust air.

A heat exchanger is to be installed in the Ewachewski residence in the near future.

4. CONCLUSIONS AND RECOMMENDATIONS

.1 General

A low energy house is one that minimizes energy requirements, and best utilizes them. This is almost always done by using large amounts of insulation by present standards, sealing the house to obtain as low an air change rate as possible and reducing the glazing surfaces on all sides of the house except south, where it is commonly increased. The Ewachewski residence is a home that seems to have taken advantage of all these points. This is evident in Table 2, Appendix C: Air Leakage characteristics of Low Energy Homes in the Winnipeg area, Appendix A: Heat Loss Calculations and Appendix D: Site Plan.

Some of the construction and energy saving techniques used in the Ewachewski residence can be utilized effectively in the housing industry in Manitoba. Conclusions relating to each feature of the home are presented below.

.2 Wall Construction

.1 Double-Wall

As noted earlier, there are two different types of wall construction.

The exposed south wall, as well as the wall separating the garage and the house, are a conventional type double wall. Two separately constructed walls are spaced approximately 5½" (140mm) apart. The walls then accommodate three layers of glass fibre batt insulation for a total R-value of 44 (RSI 7.7). The interior surface is made up of a 4 Mil polyethylene air/vapour barrier, 1" (25mm) shiplap and a wood or drywall finish yet to be installed.

The method of construction used here is acceptable. The air/vapour barrier could have been installed in a location that would have made the installation simpler and more effective.

Installation of the air/vapour barrier on the outside of the inside wall (see Figure 9) allows installation without penetration of the polyethylene for fixtures and wires, yet there is no risk of condensation problems because the air/vapour barrier is located in a position where the temperature does not fall below the dew-point.

This method also reduces the time required for detailed sealing due to reduction of possible air leakage areas.

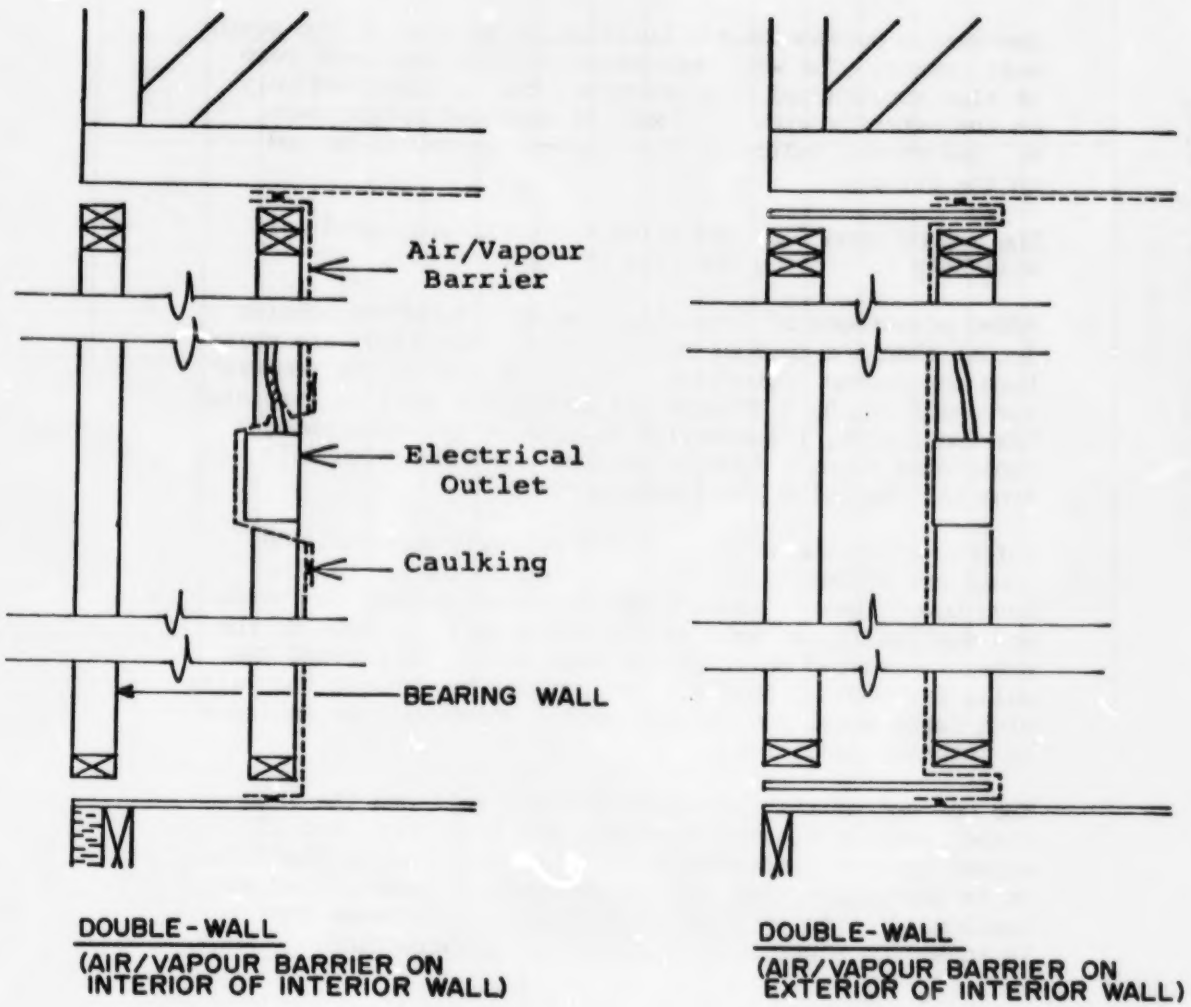


FIGURE 9

.2 Concrete Wall

The original design of the below grade wall was to be 2 x 8 pressure treated studs on 12" (305mm) centres, with 5/8" (16mm) pressure treated polywood sheathing in the exterior. Mr. Ewachewski was advised against the method by the manufacturer, of pressure treated woods, who felt the load would be too great. Considering this, the wall was built with concrete 8" (200mm) in thickness and heavily re-inforced. The interior of the wall was then framed and insulated with R-20 (RSI 3.5) glass fibre insulation as well as 3" (75mm) of expanded polystrene on the exterior as illustrated in Figure 6.

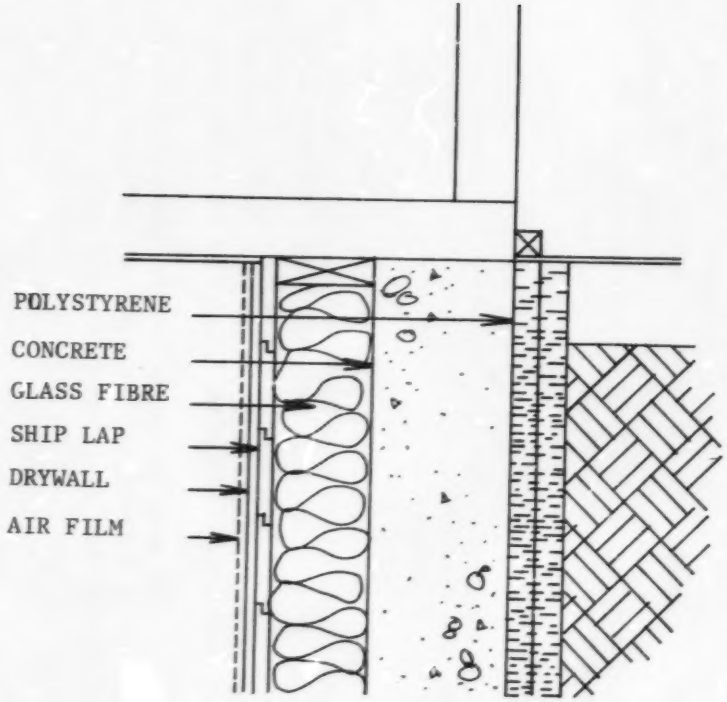
The garage portion of the building is located in the southwest corner. The wall separating it from the earth berm is also constructed from concrete, but is insulated only on the exterior with 3" (75mm) of expanded polystyrene. Mr. Ewachewski indicated that the garage may be heated in the future.

The method used for insulating the earth sheltered wall will help to prolong the life of the concrete.

Added advantages of insulating the wall from the outside (other than the obvious resistance to heat flow) are moisture and freeze protection. As can be see in the temperature profile chart (Figure 10) though the wall is insulated from the inside, the exterior insulation provides enough resistance to heat flow to prevent the foundation wall from falling below the freezing point.

Unfortunately the walls were not properly designed and could not withstand the load exerted by the earth, and have bowed inward. Bowing has occurred on both the north and east walls, as well as the south wall because of the pressure exerted on it by the east wall. To prevent the walls from bowing further, the builder has braced the walls with large metal angles (see photo) which will be enclosed in interior partitions.

The concept of the insulated concrete wall and the insulated pressure treated wood wall are both good, but if either type of construction is to be utilized in the future it is imperative that they be designed by a qualified professional. This is a major deficiency in a house that is to set an example of this type of construction.



	R	R/R_T	ΔT	T
				20°C
Inside Air Film	.68	.02	.46	
				19.5
1/2" Drywall	.45	.01	.31	
				19.2
1" Shiplap	1.25	.04	.85	
				18.4
R-20 Glassfibre	20	.57	13.61	
				4.8
8" Concrete	.9	.03	.61	
				4.2
3" Expanded Polystyrene	12	.34	8.16	
				-4°C*
TOTAL	35.28	1	24	

FIGURE 10
A TEMPERATURE PROFILE CHART

* Lowest temperature taken from a Winnipeg Meteorological Summary 1968-1972 (8 year average) of soil temperature 20 cm below grade.

.3 Lighting

Care must be taken in the selection of lighting for residences. Incandescent lights have certain advantages that make them more desirable than fluorescent lighting, even though fluorescent lighting is associated with reduced operating costs and an extended life span. Some of these advantages are: lower fixture and installation cost, less difficult to control, lower cost of replacement bulbs, more versatile than fluorescent, less stimulating and more relaxing, and also gives a better colour rendition.

It is our opinion that incandescent lighting is better suited to a residential environment than fluorescent. A home requires light to set moods, enhance colour, relax the occupants and generally be variable. This is better accomplished with incandescent lighting.

There are a total of twenty-one incandescent fixtures in the Ewachewski residence, all of which are wall mounted. Wall mounting reduces the number of penetrations to the ceiling air vapour barrier, thus reducing the potential for air and moisture leakage.

Although considerable care and effort was taken to seal electrical boxes, air leakage could still be detected where the wire entered the box. The obvious recommendation would be to reduce the number of electrical fixtures on exterior walls where there is an air vapour barrier. The other alternative would be to install the air/vapour barrier on the outside of the inside wall as previously detailed.

.4 Ventilation

The ventilation system had not yet been installed in the residence, but Mr. Ewachewski did indicate the type and model he is considering purchasing.

An air-to-air heat exchanger will be installed in the house to control humidity, odours, contaminants, etc. During the site visit of December 13, 1982, the relative humidity levels were exceeding 80% with the house unoccupied, and a low outdoor temperature. This would seem to indicate a definite need for an air to air heat exchanger when the house is occupied.

A brochure of the heat exchanger being considered by Mr. Ewachewski and a schematic of a typical installation can be found in Appendix E.

.5 Heating

An electric baseboard type heating system will be installed in the home as the main source of heat. This is well suited for a low energy home application. It provides for proper sizing, individual room control, and low installed cost.

The electric baseboard system will also be supplemented by two other heating systems. A wood burning stove will be used, which is ideally suited to this building because it will be able to provide the majority of the heat required, an added advantage to the abundance of trees located on the property, an obvious advantage over a city location where fire wood can be quite expensive. The heat gain from the wood stove will be distributed throughout the house by convection and radiation.

The third heating system that is to be installed is the radiant atrium floor solar heating system. Concrete will be poured in place over piping which will carry a heating medium from the future solar system. During construction of the building shell, the Owner installed supply and return piping for the solar collectors which is an excellent idea in any newly constructed home. This will make the future installation easier and less expensive, as well as ensuring proper design and sealing at penetrations, which would be more difficult in a retrofit situation.

.6 Windows

The advantages of having a large area of triple glazed windows, which are all located on the south exposure, is obvious. Heat gain from the south facing windows will be distributed throughout the house by convection and radiation. The windows which make up 45% of the total south wall area unfortunately produce a large heat loss during the night time. The importance of triple glazing to reduce this heat loss is very evident when a comparison is made between the triple glazed windows and single and double glazed. An estimated saving of $340 over single glazing and $90 over double glazing should be realized.

Mr. Ewachewski indicated that insulated shutters may be installed in the future. This would be an excellent way of trying to retain the heat during the time when the windows are not collecting the sun rays.

The windows are located on the outside of the double wall which leaves a sill on the inside of the wall. This does not present any problem, except that the window may not get an air flow across it. This may result in the formation of condensation in colder weather. The sill provides an aesthetically pleasing location for plants, books, sitting, etc. This type of window will result in lower energy usage in homes with substantial air circulation as a result of the 'still' air next to the inside window surface. In this home, with baseboard heating, air circulation will be minimal, and we would expect only minor reduction in energy usage. It would be our suggestion that this feature be utilized as a matter of personal preference.

.7 Floor Joist/Foundation Intersection

This area has been insulated only from the interior, both under the double-wall portion of the house and below grade concrete wall portion.

The header space between the joists, under the double-wall length of the house, has been insulated with a layer of R-20 (RSI 3.5) glass fibre batt and then a layer of R-12 (RSI 2.1) for a total of R-32 (RSI 5.6). To install this batt insulation it was necessary to build a pony wall between the footing and the underside of the floor joists so there would be frame work holding the glass fibre in place, as well as providing a surface to fasten the air/vapour barrier to. This is illustrated in Figures 11 and 12.

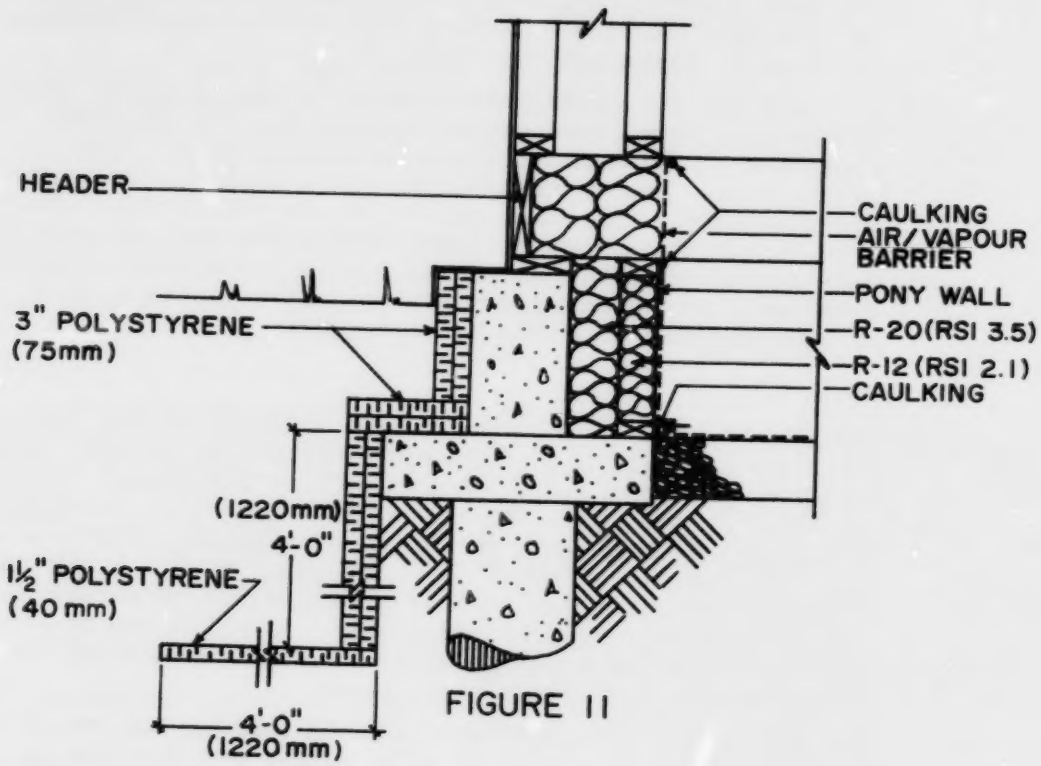


FIGURE 11

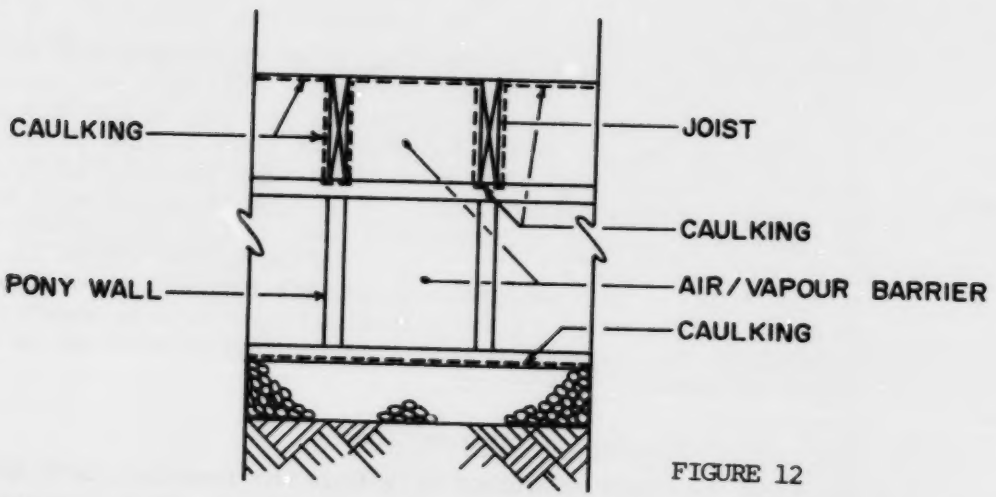


FIGURE 12

This is a more labour-intensive method than insulating and sealing with polystyrene, but the material costs are considerably less. Labour costs were not a consideration in Mr. Ewachewski's case, because the work was performed by himself. Had labour costs been a factor, the comparison would have to be looked at more closely. Also, expanded polystyrene must be covered with a fire rated material and an air/vapour barrier.

As can be seen in Figure 11, the exterior of the header is left uninsulated. Insulating this would be a good compliment to the interior insulation, because the interior insulation cannot cover the ends of the floor joists whereas exterior rigid insulation can. Because of the construction technique used here, adding insulation to the exterior is not possible.

The joist space at the header is insulated almost the same way at the intersection of the below grade concrete wall portion of the house. The only difference is that a 6" (150mm) pony wall, insulated with R-20 (RSI 3.5), is used as shown in Figure 13.

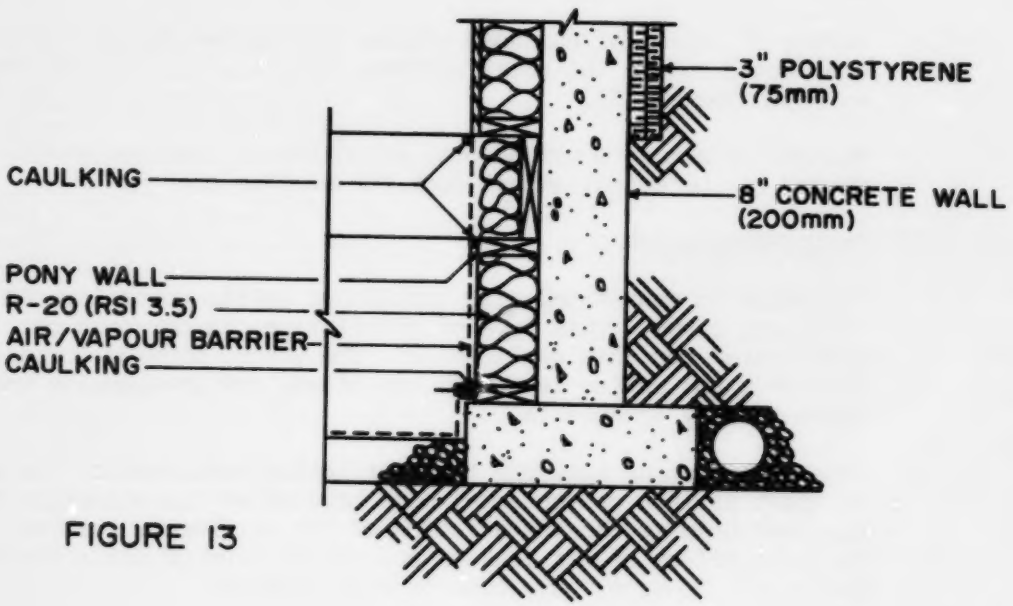


FIGURE 13

Again the header area has not been insulated on the exterior of the concrete wall. In this case insulation should not be considered as the wall is below grade.

.8 Crawlspace

As can be seen in Figures 11 and 13, the wall of the crawlspace is constructed of poured-in-place concrete and insulated with glass fibre batts on the interior. On the exposed wall portion of the house, the grade beam is also insulated on the exterior as illustrated in Figure 11. This method of insulating with rigid polystyrene 4' (1220mm) down and then 4' (1220mm) out will ensure there is no frost penetration to the crawlspace floor, or the footings, as well as adding thermal resistance to the wall. Insulation of the crawlspace wall on the exterior of the below grade portion of the house was not necessary because of the interior insulation, and the depth below grade where freezing would not be experienced.

.9 Crawlspace Floor

The crawlspace floor is not insulated, but is completely covered with a moisture barrier. Because of the large area of the house, the floor has a heat loss of about 1/3 of the total for the entire building.

Adding 2" (50mm) of expanded polystyrene to the entire floor area would reduce the total building heat loss or heating cost by approximately 7%.

Whether or not it would be cost effective to insulate would depend on the actual annual cost for heating energy.

.10 Attic Ventilation

The attic is ventilated with continuous soffit vents located under all eaves. This type of ventilation, in our opinion, is best suited for this application. The vents, provide for air flow over the entire length of the attic, are inexpensive and aesthetically acceptable.

In a home such as this one the ventilation requirements are not as great as in a conventional home because of the attention that has been paid to the installation of the air/vapour barrier. The possibility of air leakage and the problem of attic frost, due to air leakage, have been greatly reduced.

.11 Earth Sheltering

Based on the information provided in this report, the bermed wall construction lends itself well to rural house construction, where land is relatively inexpensive, and physically well suited. Within the city, bermed wall construction would likely not prove to be cost effective, due to smaller lot sizes, land-fill requirements, elevation of services, etc. Houses similar to the Ewachewski residence may be considered on very large city lots.

.12 Domestic Water Heating

The water heating system has not yet been installed, but the Owner indicated that he wished to use a small electric water heater that would operate only as required, and would be controlled by a timer to operate only during the morning and evening when there is a demand. All supply piping will be insulated.

This will reduce somewhat the standby losses of the water heater with resulting energy savings.

5. CALCULATIONS & TESTS

.1 Heat Loss

A calculation of heat loss through the building components or "Design Heat Loss" of the Ewachewski residence can be found in Appendix A. This type of calculation is used to size a heating system because it is based on the coldest conditions imposed on the house. The design heat loss of the Ewachewski residence is 11.1 kW.

In a low energy house the design heat loss should not be used to estimate the consumption. The reason for this is that the design heat loss does not take into account the placement of the building on the site, colours of the walls, and the orientation of windows. These are all major factors when dealing with relatively small figures.

For estimation of the annual consumption, a 'net annual' method was used, which takes into account orientation of walls, colours and windows. This can also be found in Appendix A. This method is used to determine the annual consumption for the exposed areas of the house, and does not account for below grade portions, where the design heat loss must be used in conjunction with this method. The estimated annual consumption for heating the Ewachewski residence is 16,831 kWh, which would translate into a cost of approximately $426.00 based on current rates for electricity.

.2 Air Leakage Test Description

The air leakage test was performed by a Minnedosa company, D.R.S. Enterprises Limited, using a machine called the 'Infiltrometer'. The infiltrometer (see Appendix B) is placed in a doorway and by the use of a fan creates a negative pressure inside the building. Corresponding pressure readings of the differential across the wall of the house and at the throat of the air flow measuring nozzle are taken. A series of these points form the characteristic curve for that particular building. A computer print-out for the Ewachewski residence as well as the description of the data are found in Appendix B. The characteristic curve has also been plotted to more clearly illustrate what the curve would look like had it been plotted manually on full log paper.

6. COMPARATIVE EVALUATION

Three main factors in determining the effectiveness of Low Energy houses are insulation levels, minimizing natural air change and glazing orientation. Unfortunately glazing orientation is a factor that has not been well documented, so the comparative evaluation will concentrate on insulation levels and air leakage characteristics. To assist in our comparison of insulation levels we have in Table No. 1, Appendix C, charted the various levels for the following homes.

.1 The Manitoba Hydro Super Energy Efficient Home (SEEH).

.2 The 1980 Canadian Energy Association Standards (1980 CEA).

.3 The 1978 Manitoba Building Code (1978 MBC).

.4 The Saskatchewan Conservation House (SCH).

.5 Energy Efficient Flair Home - Project #3 (FH#3).

.6 Carroll Residence, Swan River (Underground house).

.7 Neufeld Residence, Steinbach.

.8 Ewachewski Residence, Shoal Lake (Underground).

From Table No. 1 it can be seen that the Ewachewski home does not lack in insulation as compared to the other houses having levels greater than or almost equal to them.

The calculated annual energy consumption for the Ewachewski residence in compared with five other homes as shown below.

	GJ/m²/yr.	kWh/ft.²/yr.
Ewachewski Residence	.23	5.84
Neufeld Residence	.093	2.39
Carroll Residence	.16	4.24
SEEH	.11	2.98
CEA	.37	9.68
MBC	.68	17.87

NOTE: Basement areas are included in analysis, but crawlspace areas are not. As seen in the above table energy consumption in the Ewachewski residence would be expected to surpass any existing standards as well as consumption in other low energy homes.

Table No. 2 in Appendix C is a comparison of air leakage characteristics of low energy homes in the Winnipeg area tested by the Infiltrometer. Again by using the figure located in the relative tightness column we can see that the Ewachewski residence fares quite well amongst other low energy homes in respect to air leakage.

Table No. 3 is a comparison of the Ewachewski underground house heat loss with the same house had it not been constructed below grade. As shown in Table 3, if all walls were of the double-wall type and exposed to the outside the loss would be only 0.5 kW greater than is the underground version. Also the exposed wall house may have a higher air change rate, thus a higher heat loss due to wind which the earth sheltered home would not.

In general the design and construction techniques implemented in the Ewachewski house set it apart from any conventional house as well as most low energy houses. Not only is the house designed to be low in energy consumption, it is also designed to be unique and innovative. In addition to the usual low energy features such as; large amounts of insulation, large areas of south facing windows, detailed sealing, etc., it is the unique features such as the bermed wall and atrium that set it apart from conventional housing. It is unfortunate that this home must serve as a lesson in what not to do in constructing an earth retaining wall, but it emphasizes the fact that this type of wall requires careful consideration and design in any such future project.

It is difficult to make a comparative evaluation of construction and related costs between the Ewachewski residence and conventional housing, because the majority of construction is done by the Owner. Items that could be major contributors to the construction cost of a contractor built earth bermed home are not accounted for in this case. Mr. Ewachewski's own labour costs him nothing, as well as the fill required to earth berm his home. For this reason it is difficult to attempt any cost comparison and evaluation.

APPENDIX A

Heat Loss Calculations

EWACHEWSKI RESIDENCE : DESIGN HEAT LOSS

Component	Area m^2	RSI	U	ΔT °C	Heat Loss kW
Ceiling	268	10.5	.10	55	1.404
Walls (Exposed)	57	7.7	.13	55	.408
Walls - (Underexposed Crawlspace)	26.3	7.7	.13	24	.082
(Under bermed Crawlspace)	32.3	3.5	.28	13	.119
(Bermed)	103.4	5.6	.18	16	.298
Doors	3.3	1.4	.71	55	.129
Windows	23.7	.53	1.89	55	2.464
Air Change	817 m^3	.10/hr	.65	55	2.903
Floor	268	4.4	.23	55	3.350
Total					11.08

SUMMARY OF HOUSE CONSTRUCTION DATA AND CALCULATED NET HEAT LOSS COMPONENTS

DESCRIPTION		ORIENTATION				TOTAL FOR ALL ORIENTATIONS
		NORTH	SOUTH	EAST	WEST	
WINDOWS	Area, m^2		23.7			23.7
	Heat Loss Factor, kWh/m^2		-142			
	Heat Loss, kWh/yr		-3365			-3365
EXTERIOR WALLS	Area, m^2	39.3**	17.7			57
	Resistance, m^2K/W	7.74	7.74			
	Heat Loss Factor, khK	128	94			
	Heat Loss, kWh/yr	650	215			865
BASEMENT WALLS ABOVE GRADE	Area, m^2					
	Resistance, m^2K/W					
	Heat Loss Factor, khK					
	Heat Loss, kWh/yr					
EXTERIOR DOORS	Area, m^2	1.7**	1.7			3.4
	Resistance, m^2K/W	1.4	1.4			
	Heat Loss Factor, khK	128	94			
	Heat Loss, kWh/yr	155	111			266
CEILING	Area, m^2	268				268
	Resistance, m^2K/W	10.6				
	Heat Loss Factor, khK	94				
	Heat Loss, kWh/yr	2377				2377
INFILTRATION	Average Infiltration Rate, m^3/h	147				147
	Heat Loss Factor, kWh^2/m^3	47				
	Heat Loss, kWh/yr	6912				6912
TOTAL HEAT LOSS =						7055

**It should be noted that in the case of exterior walls, doors etc., the annual heat loss in kWh is the product of the area and the heat loss factor divided by the resistance.*

** Not actually north, but always shaded by garage.

CONSUMPTION CALCULATION FOR EWACHEWSKI RESIDENCE

Component	Heat Loss (kW)
Bermed Wall	.298
Crawlspace Walls	.201
Crawlspace Floor	3.350
Total	3.849

3.849 kW x 2540* = 9,776 kWh Annually
+7,055 kWh Annually from Net Annual Calculation
16,831 kWh Est. Annual Consumption

* $\frac{\text{Degree Day x Hours in a Day}}{\text{Design Temperature Difference}}$

Heating Cost

Given the run-off rate for electricity of $.0253/kWh, the annual heating cost is estimated as follows:

$$\frac{\$.0253}{\text{kWh}} \times 16{,}831 \text{ kWh} = \$426$$

APPENDIX B

The Infiltrometer and Air Leakage Tests

"Air Leakage and the Infiltrometer"

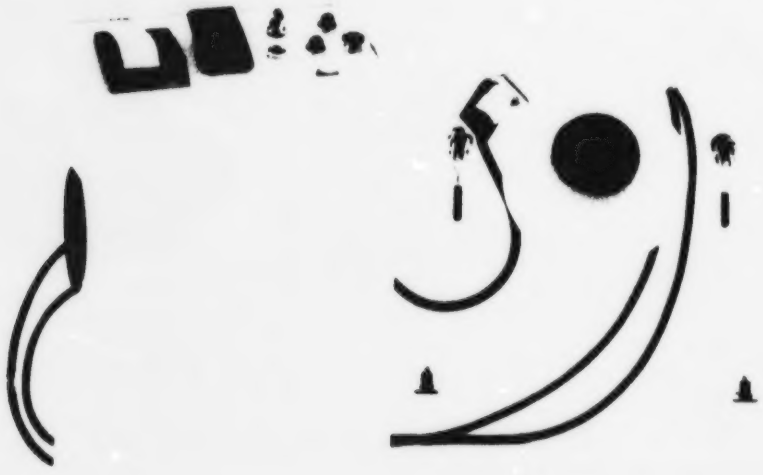
The importance of reducing uncontrolled air leakage in residential dwellings cannot be over-emphasized. It is the major component of heat loss in almost every home in North America.

The Canadian Government has recently established a committee on Airtightness of Buildings, charged with the responsibility of developing an airtightness standard for residential construction. The National Research Council of Canada has recognized the importance of airtightness in a number of its publications.[1]

infiltrometer

ener-corp

THE ENERGY MANAGEMENT COMPANY



A number of research organizations in the United States have drawn some startling conclusions in the air leakage work they have been involved in. Princeton University, for instance, have determined that "...house-to-attic warm air leaks...result in the waste of almost 20% of all the home heating energy (2% of all energy) used in the United States. That is equivalent to wasting over 600,000 barrels of oil a day."[2]

Lawrence Berkeley Laboratory have concluded in one of their publications[3] that "for homes in the United States...air leakage imposes a 30% to 40% burden on the energy load of a typical house."

Based on air leakage measurement practices developed in Sweden, the American Society for Testing and Materials (ASTM) has proposed a standard for air leakage measurement by the fan pressurization method.

The Infiltrometer has been designed to exceed all requirements of the proposed standard. The result is a device capable of automatically and accurately determining the air change rate of virtually every single detached residential structure in North America. Field data and results are recorded by an electronic printer to add a significant degree of integrity to this sophisticated device.

Copies of the above-noted publications and other informational data is available on request.

Call Toll Free
1-800-228-2606
24 hours a day—7 days a week

1. HANDEGORD, G. O., The Need for Improved Airtightness in Buildings. National Research Council of Canada, Division of Building Research, Building Research Note No. 151.
2. DUTT, G. S., If Home Energy Saving is such a Good Idea, Why don't more People do it?, Appendix A, Centre for Energy and Environmental Studies, Princeton, University.
3. GRIMSRUD, D. T., et al., Calculating Infiltration: Implications for a Construction Quality Standard, Energy and Environment Division, Lawrence Berkeley Laboratory.

ENER-CORP MANAGEMENT LIMITED **HEAD OFFICE:** 2 Donald Street, Winnipeg, Manitoba, Canada R3L 0K5 (204) 477-1283
EASTERN CANADA: 440 St. Joseph Boulevard, Hull/Ottawa J8Y 3Y7 (819) 777-4446
UNITED STATES: 359 Route 111, Smithtown, New York 11787 (516) 724-2111

ENER-SEAL

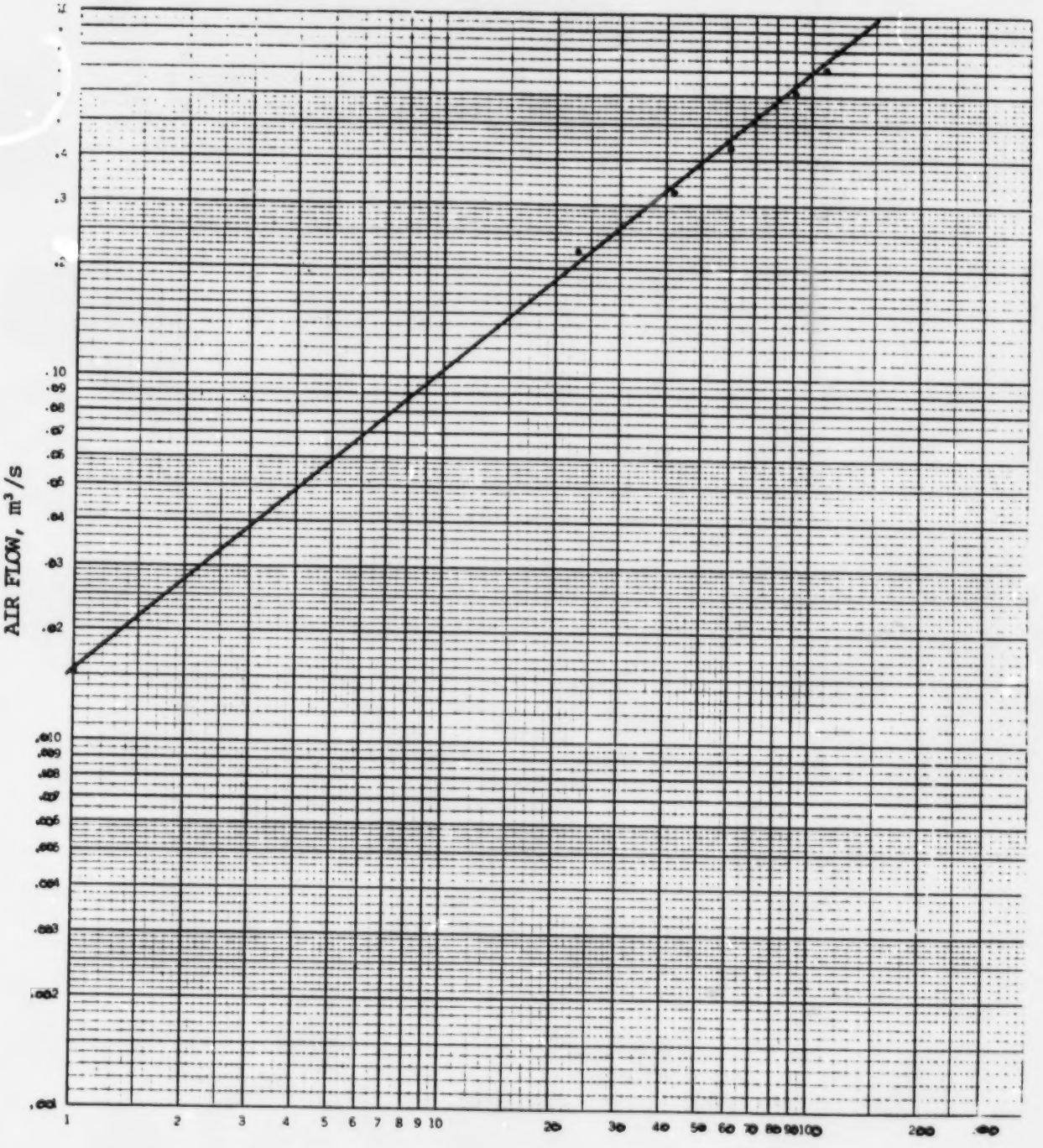
VOL/AREA/TEMP/PRES

817.	MT3	--- Gross Heated Volume, m^3
352.	MT2	--- Gross Exposed Surface Area, m^3
20.	TEMP	--- Inside Air Temperature, °C
101.4	PRES	--- Barometric Pressure, kilopascals

H. PRS/N. PRS/FLOW

118.	HP	--- House Pressure, Pascals
2520.	NP	--- Nozzle Pressure, Pascals
771.4036016	Q	--- Flow Rate, litres per second
110.	HP	
1990.	NP	
685.338899	Q	
90.	HP	
1525.	NP	
599.7885668	Q	
60.	HP	
750.	NP	
420.3254477	Q	
42.	HP	
440.	NP	
321.7731353	Q	
26.	HP	
210.	NP	
222.1328739	Q	
.9888126589		---------- Correlation Coefficient
.0421173187	MT2	--- Equivalent Leakage Area, m^2
1.63784153	50PA	--- Air Changes Per Hour @ 50 Pascals
.0872552072	I	--- Infiltration Rate
.2875224909	MM/S	--- Relative Tightness, mm/s
.0157367359	C	--- Flow Coefficient, $m^3/s.\ Pa^N$
0.808299277	N	--- Flow Exponent, dimensionless

EWACHEWSKI RESIDENCE



Description of Data

The input and output data of the Ewachewski residence air leakage test, before and after sealing, is shown in Figure 14. The characteristic curve has also been plotted in Figure 15. This data will now be described in detail.

Heated Volume: The total heated volume of a structure is required to enable the air change rate at a 50 Pascal pressure differential to be determined. This item is also required to calculate the infiltration rate.

The Exposed Surface Area: This piece of information is necessary to determine the specific air flow rate of the structure.

The Inside Temperature: Because the density of air varies with temperature, the air flow rate through the nozzle must be corrected so that all air flow rates are reported at the same air density.

Barometric Pressure: The density of the air is also affected by the barometric pressure. For this reason this item is also required so that the appropriate correction factor can be applied.

In each case, the air flow rate is corrected and printed to report the air flow rate at standard temperature and pressure conditions, that is, 20°C and 101.4 kilopascals.

House Pressure: This is the envelope pressure produced by the Infiltrometer and is measured in Pascals.

Nozzle Pressure: This is the pressure created by the air flow at the throat of the nozzle, and is measured in Pascals.

Air Flow Rate: The nozzle is a carefully calibrated, long radius ASME nozzle with known characteristics. The relationship between the nozzle pressure and the air flow rate has been determined in the laboratory and the nozzle pressure is then used to calculate the corresponding air flow rate.

Correlation Coefficient: In order to determine the accuracy of the pressurization data, some indication of how well the points 'fit' on a straight line must be included. The determination of the correlation coefficient is a complicated but very accurate means of ensuring an acceptable 'fit'.

The Infiltrometer program automatically calculates the correlation coefficient, but will print no output data unless the correlation coefficient is greater than .98.

Equivalent Leakage Area (ELA)

This item is a measure of the 'hole' size in the envelope of the structure. The accepted means of calculating this value is based on the equation for turbulent flow through a sharp edged orifice in a thin wall. In the laboratory, it has been found to correlate well with the actual size of a hole introduced into the envelope.

Air Change Rate at 50 Pascal Pressure Differential

The air change rate is the number of times that the entire air volume within the structure changes each hour at a specific pressure differential. The pressure differential of 50 Pascals is somewhat arbitrary but was selected to conform with the reference pressure used internationally to report air change rates. This value is determined by dividing the air flow rate per hour at a 50 Pascal pressure differential by the heated volume of the structure.

'I' Infiltration Rate

It is very important to note that air tightness testing will not necessarily result in an accurate determination of the infiltration rate. This is because the infiltration rate is dependent upon many factors which are peculiar to each structure, such as the internal resistance offered by the walls, floors, etc., the location of the holes in the envelope of the structure, the proximity to other buildings, etc. It has therefore been difficult to establish an accurate correlation between depressurization data and the infiltration rate.

Recently, the National Research Council of Canada published a paper in which such a correlation was presented. The report suggests that the depressurization data can be used to predict the infiltration rate with some degree of accuracy, say, plus or minus 25%. The infiltration rate calculated and printed is based on this research paper. It should be reiterated that the infiltration, or air change rate, is not a constant but varies with the outside temperature as well as the wind speed and direction.

Relative Tightness

This item is very useful for comparing the air tightness of different sized structures. The relative tightness can be thought of as the specific air flow rate, in which the measured air flow rate at a particular pressure differential is divided by the gross exposed surface area to produce an air flow rate per square metre. One can then logically compare different sized structures on the basis of relative tightness. It should be noted that the units of relative tightness are millimetres per second, which can be considered the average velocity of the air entering the structure.

The relative tightness can be calculated at any pressure differential, but 10 Pascals has been chosen to correspond with the pressure at which the ELA is determined.

The relative tightness of the differential structures can vary widely depending on the construction techniques employed and the attention to details shown by the original contractor.

Leakage or Flow Coefficient

The definition of this item is that it is equal to the value of the flow rate when the pressure differential across the envelope of the structure is 1 Pascal. This item is very useful for reporting the results of the air leakage tests, as it is one of the two items required to produce the leakage curve without the necessity of recording all of the pressure data.

Leakage or Flow Exponent

The flow exponent is the slope of the air leakage curve when corresponding values of flow rate and pressure are plotted on full log graph paper. From the physics of air flow, this value must always be above 0.5 but not greater than 1.0.

This item is useful for two reasons: Its value, along with the leakage coefficient, can be used to generate the leakage curve with no additional pieces of information being required and the flow exponent can be used to indicate the size of holes that predominate the air leakage.

In general terms, if the value of the flow exponent is in the vicinity of .55, then the predominant holes in the envelope of the structure are relatively large, that is, greater than 2mm. If the flow exponent is towards the opposite end of the scale, say .85, then the type of air leakage points would be relatively fine, such as hair line cracks along baseboards.

APPENDIX C

Comparison Tables

HOUSE	INSULATION LEVEL RSI (R-VALUE)				DESIGN HEAT LOSS
	ROOF	WALL	BSMT. WALL	FLOOR	kW
Ewachewski Residence (268m²)	10.6 (60)	7.7 (44)	5.6 (32)	-	11.1
Neufeld Residence (124m²)	10.6 (60)	8.5 (48)	6.7 (38)	1.8 (10)	4.3
Carroll Residence (280m²)	7.6 (43)	5.3 (30)	6.5 (37)	-	7.7
SEEH (103m²)	9.9 (56)	7.0 (40)	5.3 (30)	1.1 (6)	4.0
1980 CEA (103m²)	7.0 (40)	3.5 (20)	2.1 (12)	-	13
1978 MBC (103m²)	5.8 (33)	2.1 (12)	1.2 (7) to .6m below grade	-	24
SCH	10.6 (60)	7.7 (44)	3.5 (20)	-	-
FH#3 (98m²)	9.7 (55)	8.3 (47)	4.8 (27)	-	4.5

TABLE 1

COMPARISON OF INSULATON LEVELS IN LOW ENERGY HOMES

House Type	Equivalent Leakage Area m^2	Air Changes Per Hour @ 50 Pa	Flow Coeff., (C) $m^3/s\ Pa^N$	Relative Tightness mm/s	Flow Exponent N
Ewachewski Residence	.042	1.64	.016	.287	.81
Neufeld Residence	.018	.72	.008	.17	.72
Carroll Residence	.074	2.40	.036	.568	.70
Four Level Split	.028	1.30	.014	.25	.69
Single Storey with Basement	.021	1.40	.010	.28	.68
Single Storey with Basement	.005	.27	.002	.05	.75
Two Storey with Crawlspace	.003	2.05	.014	.31	.76
Two Storey with Basement	.005	2.05	.031	.42	.63

TABLE 2

AIR LEAKAGE CHARACTERISTICS OF LOW ENERGY HOMES (WINNIPEG AREA)

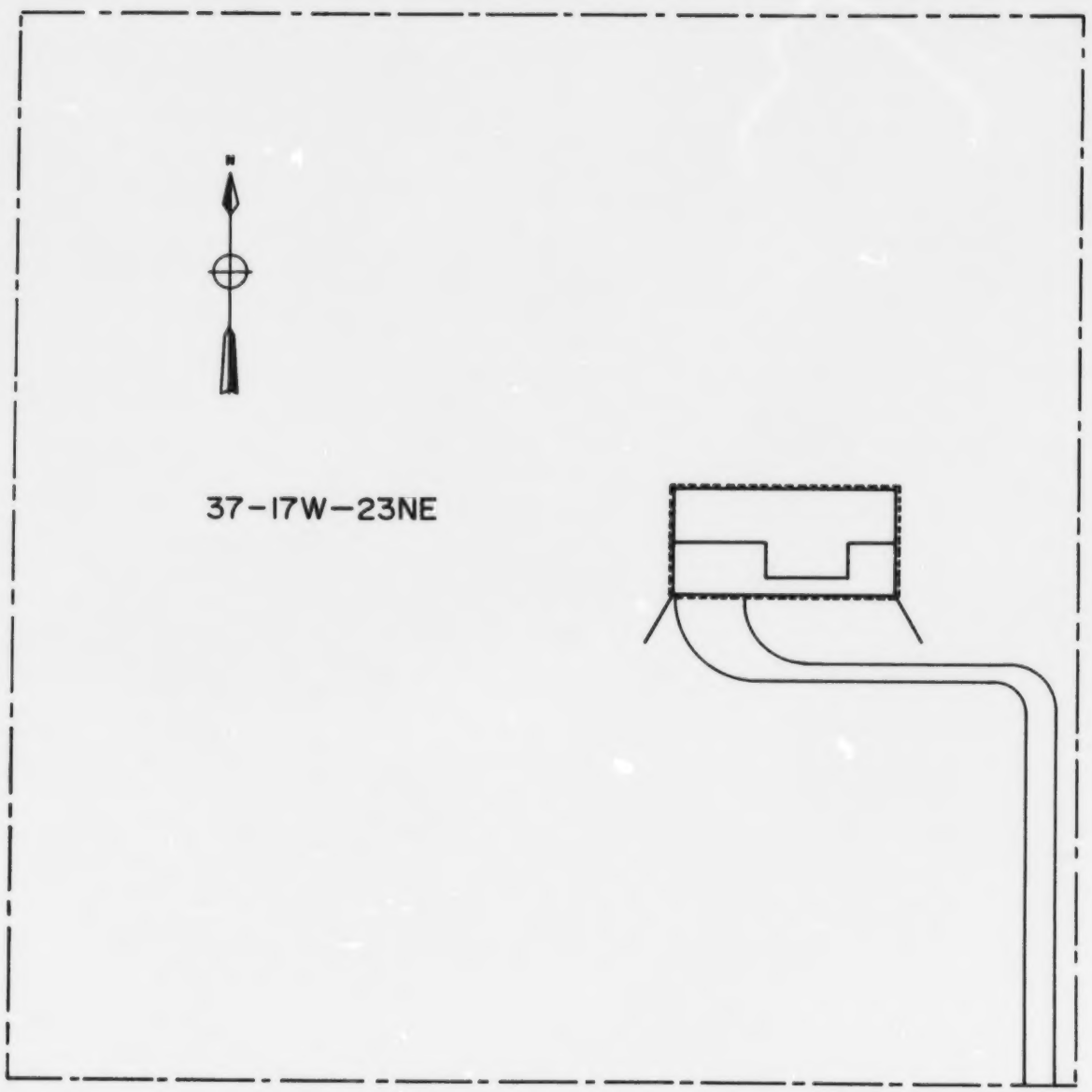
Component	Heat Loss of Bermed House, kW	Heat Loss If all wall Exposed, kW
Ceiling	1.404	1.404
Walls (Exposed)	.408	1.143
Walls (Bermed)	.298	-
Crawlspace Wall (under bermed)	.119	-
Crawlspace Wall (under exposed)	.082	.182
Doors	.129	.129
Windows	2.464	2.464
Air Change	2.903	2.903
Floor	3.350	3.350
Totals	11.08	11.58

TABLE 3

COMPARATIVE HEAT LOSS

APPENDIX D

Site Plan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APPENDIX E

Enerex 250 Heat Exchanger

ENEREX 250 Air-to-Air Heat Exchanger installation instructions:

The ENEREX 250 must be installed in a horizontal position and has been designed to fit between floor joists spaced at 16" on centre, or greater.

Scouten Mitchell Sigurdson
WINNIPEG, MANITOBA
JAN 5 1983

Included with the ENEREX 250 are:

- (2) Centrifugal fans
- (1) Defrost control c/w, on/off switch and provision for 6' automatic or manual switches in high humidity areas
- (1) Dehumidistat
- (1) Removable core
- (2) Wall end caps
- (1) 10 ft. length of flexible duct

Locating the ENEREX 250

A location close to the foundation wall central to most areas being ducted to the ENEREX 250 should be selected. Two five (5") inch holes should be drilled in the foundation wall to accomodate the fresh air supply duct and exhaust air exit duct to and from the heat exchanger. Spacing of these two holes should be at least five (5') feet apart or around a corner from one another.

Installation

STEP 1: Place the ENEREX 250 between the floor joists with the access door, with drain, facing down, and the "Fresh Air In/Exhaust Air Out" side nearest the foundation wall (see Figure 1).

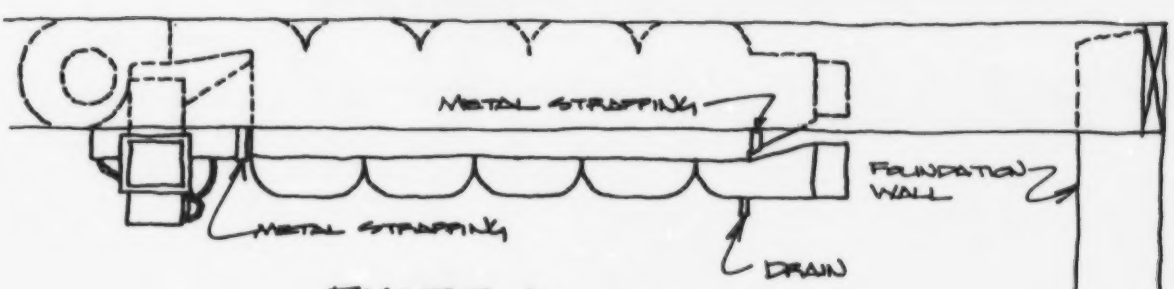


FIGURE 1

STEP 2: Fasten metal strapping to underside of the adjacent floor joists under each end of the heat exchanger as shown in Figure 1.

STEP 3: Drill two five (5") inch holes in the foundation wall at desired location and install wall end caps (see Figure 2). Exhaust air end also requires a back draft damper and the fresh air inlet end cap requires an insect screen.

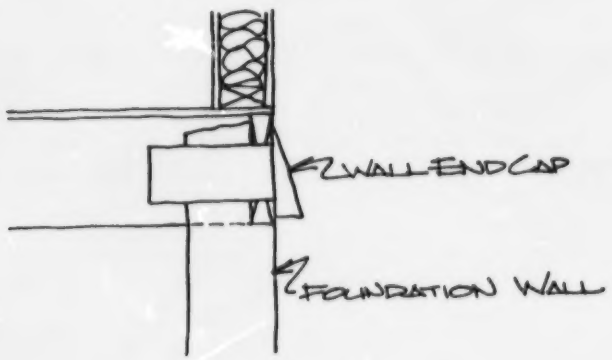


FIGURE 2

STEP 4: Attach 5" diameter flexible insulated ducts to the end caps and run ductwork to heat exchanger. Seal all joints with duct tape. Note that the duct bringing the fresh air in should run straight down the joist space through the foundation wall. The exhaust opening on the heat exchanger, which hangs below the floor joists may then be ducted outside by running the ducting perpendicular to the floor joists to another foundation wall or over a few joist spaces and then parallel to the floor joists out the same foundation wall as the fresh air intake (see Figure 3).

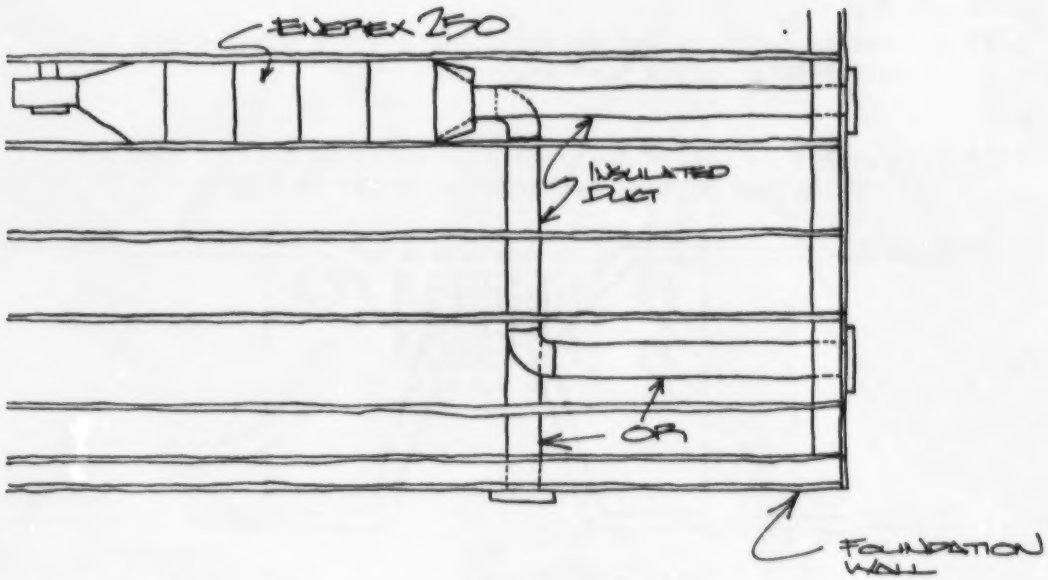


FIGURE 3

STEP 5: A 5" diameter duct will be required to remove air from high humidity areas such as kitchens and bathrooms (see Figure 5). A five (5") inch diameter duct may be run to the farthest source and branches taken off for other areas. In most cases a 4" diameter duct is required to connect the dryer exhaust where an additional lint screen should be installed.

STEP 6: The outlet on the ENEREX 250 (marked "Fresh Air Out") may be ducted into the return side of a forced air heating system or "dumped" directly into the basement.

ENEREX 250 Control System

The ENEREX 250 is controlled either automatically by a de-humidistat, manually by a switch, or both. The ideal location for a de-humidistat would be near a wall-mounted thermostat. Switches could also be located in the kitchen, bathroom and laundry areas to manually override the de-humidistat.

The ENEREX 250 is a 120/24V system with all connections made external to the control box. The power supply for the heat exchanger is 120V and all switches and de-humidistats are of the 24V type.

STEP 7: Locate switches and de-humidistats where desired and run wires back to the heat exchanger.

STEP 8: Connect switch or de-humidistat wires to back of control box located on heat exchanger as shown in Figure 4.

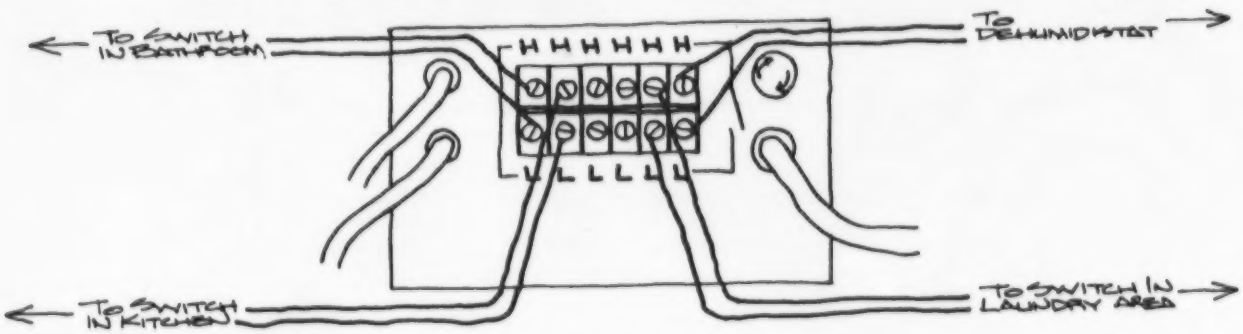


FIGURE 4

STEP 9: Plug the ENEREX 250 into a 120 volt receptacle.

STEP 10: Push the red button on the face of the control box to energize the electrical circuits. The illuminated red light next to the red button will indicate this condition.

ENEREX 250 Maintenance

The only maintenance the ENEREX 250 will require is a periodic cleaning of the heat exchanger core. This is done by removing the access panel and then spreading the sides of the unit to allow the core to be slowly pulled out of the heat exchanger. The inside of the case should be vacuumed after removing the core. The core may now be washed by the use of a hose. After drying, the core may be placed in the case. To make replacement easier, we recommend spraying the foam rubber seals on each end of the core with a silicone spray. Cleaning the core should be done at least twice a year.

In addition to cleaning the core, the dryer lint screen should be cleaned after each load, and the grease filter in the stove hood at least once a month.

STEP 11: Connect drain on heat exchanger to a hose with a ½" I.D. and run hose to the nearest household drain.

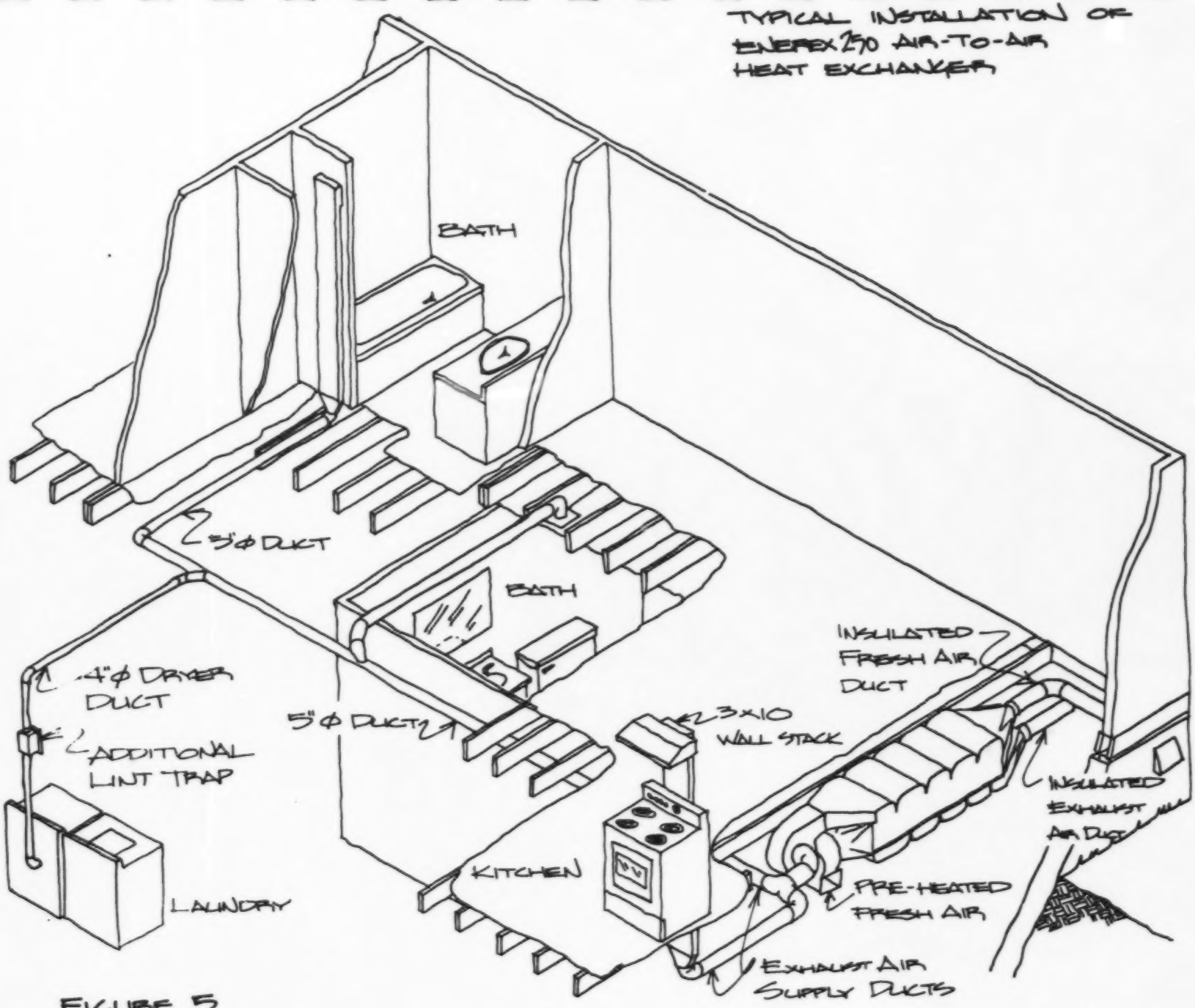
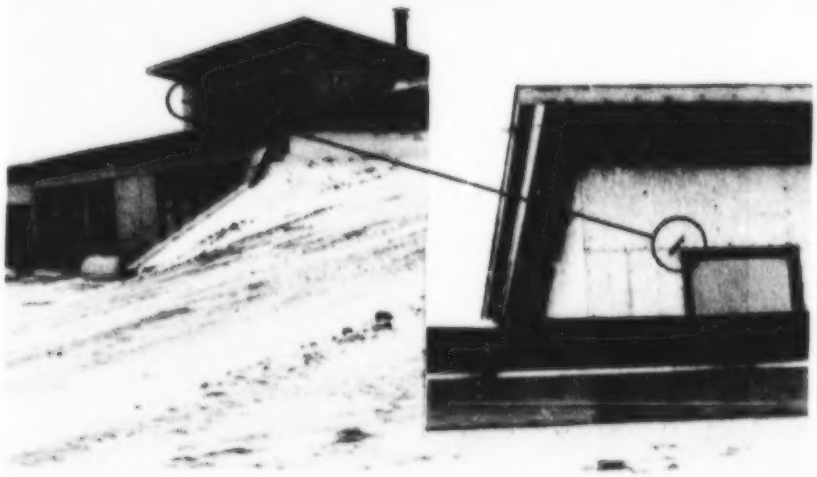

TYPICAL INSTALLATION OF ENERFLEX 250 AIR-TO-AIR HEAT EXCHANGER
BATH
3" ϕ DUCT
BATH
4" ϕ DRYER DUCT
ADDITIONAL LINT TRAP
LAUNDRY
5" ϕ DUCT
3x10 WALL STACK
INSULATED FRESH AIR DUCT
INSULATED EXHAUST AIR DUCT
KITCHEN
PRE-HEATED FRESH AIR
EXHAUST AIR SUPPLY DUCTS

FIGURE 5

APPENDIX F

Photographs

View looking from south-east.
Detail shows piping penetrations for future solar system.

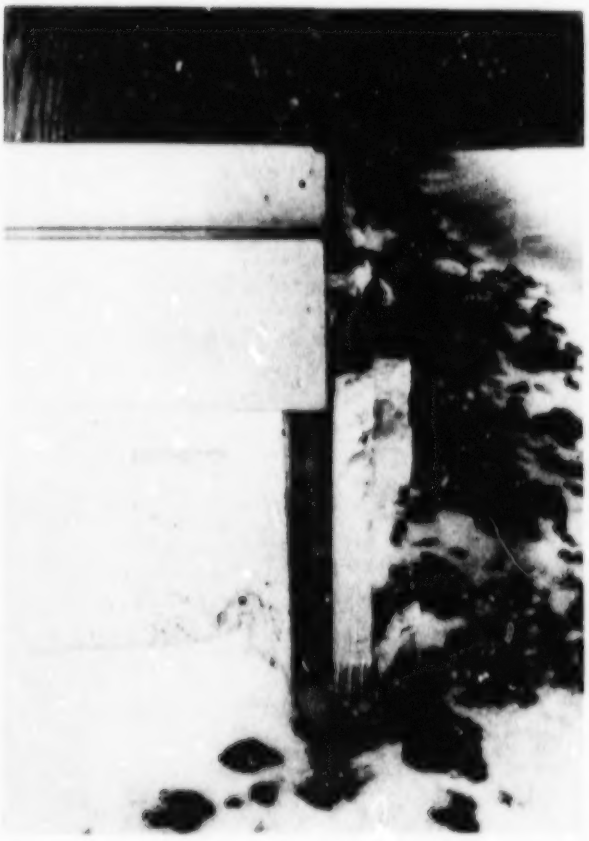


View looking from south-west.

View looking from north-west.

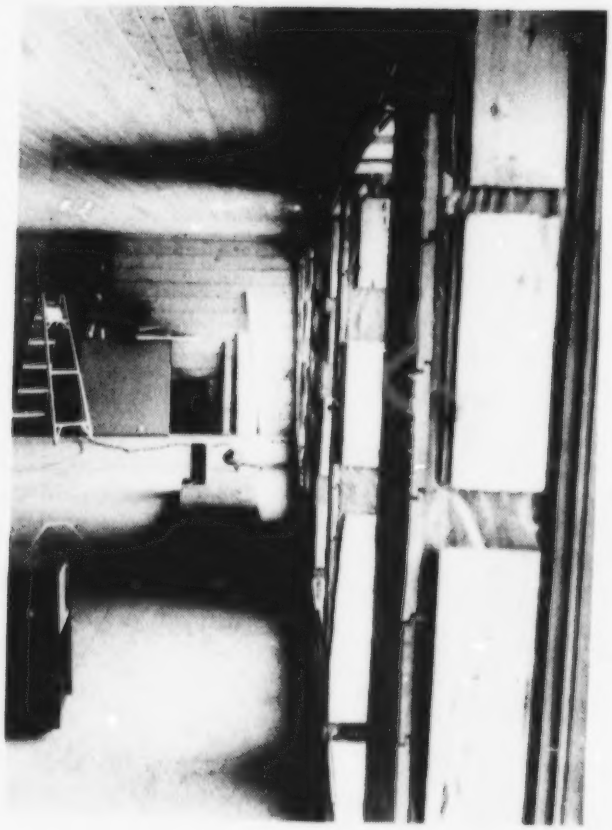
View looking from north-east.

Detail of south wall/grade beam intersection.

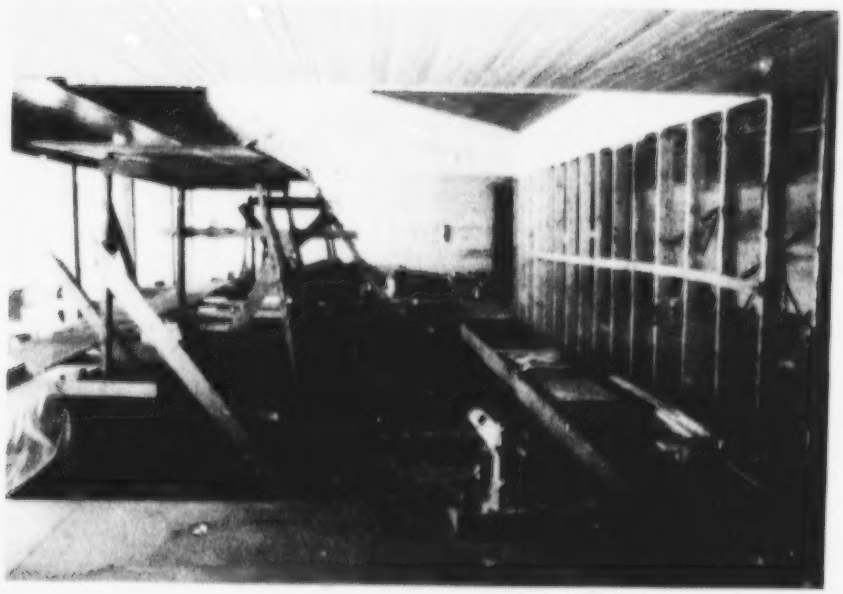


Detail of north-east corner of house.

Upper Atrium



Interior South Wall

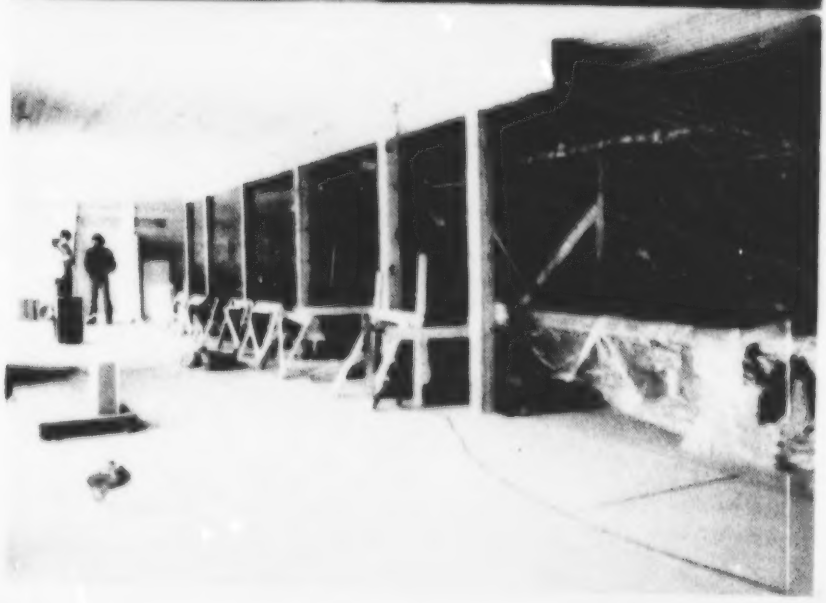


Atrium

View looking south-east through Atrium.

North wall braces.

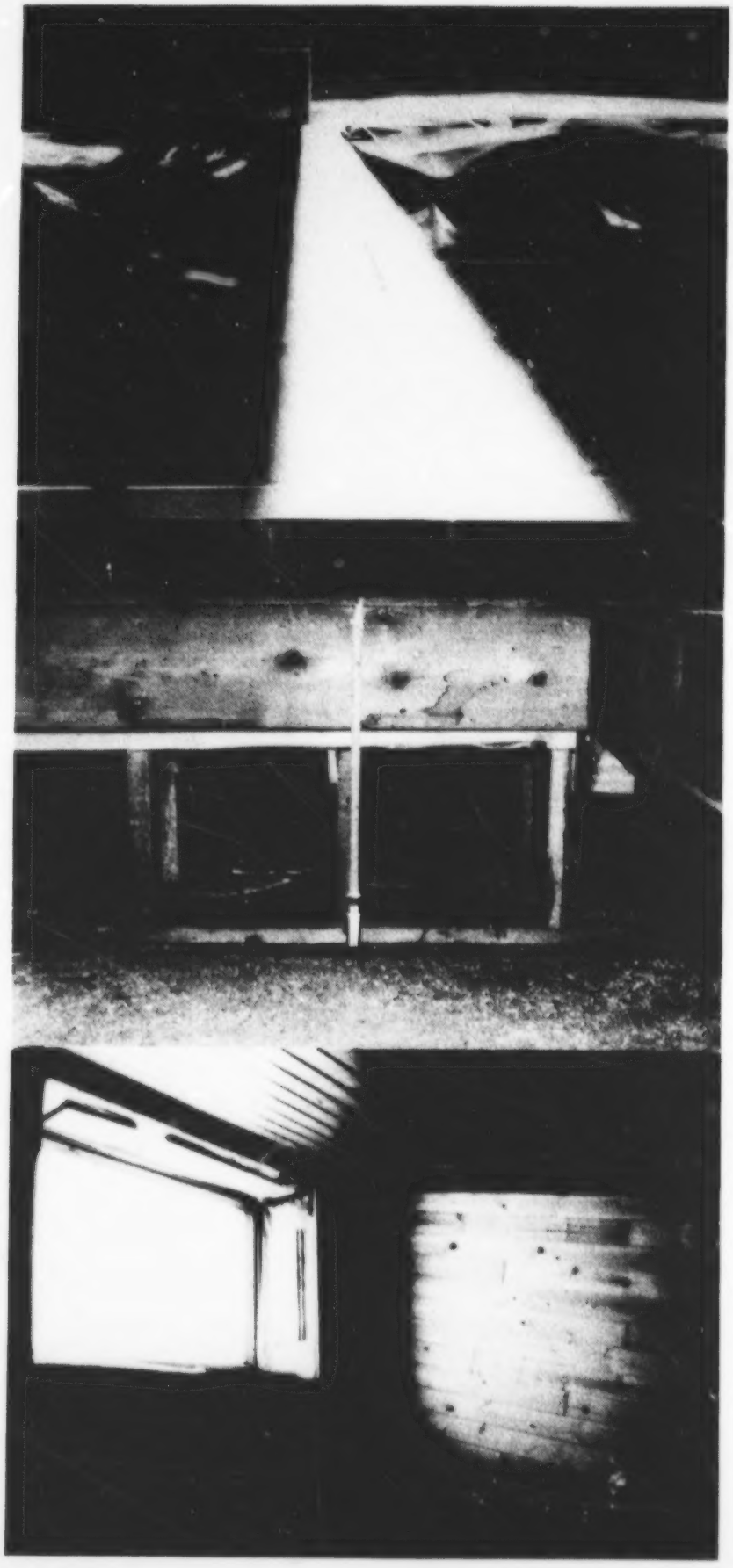
View looking north-west through Atrium.



Wire penetration through top of interior partition.

View from Atrium into Crawlspace.

Atrium window.



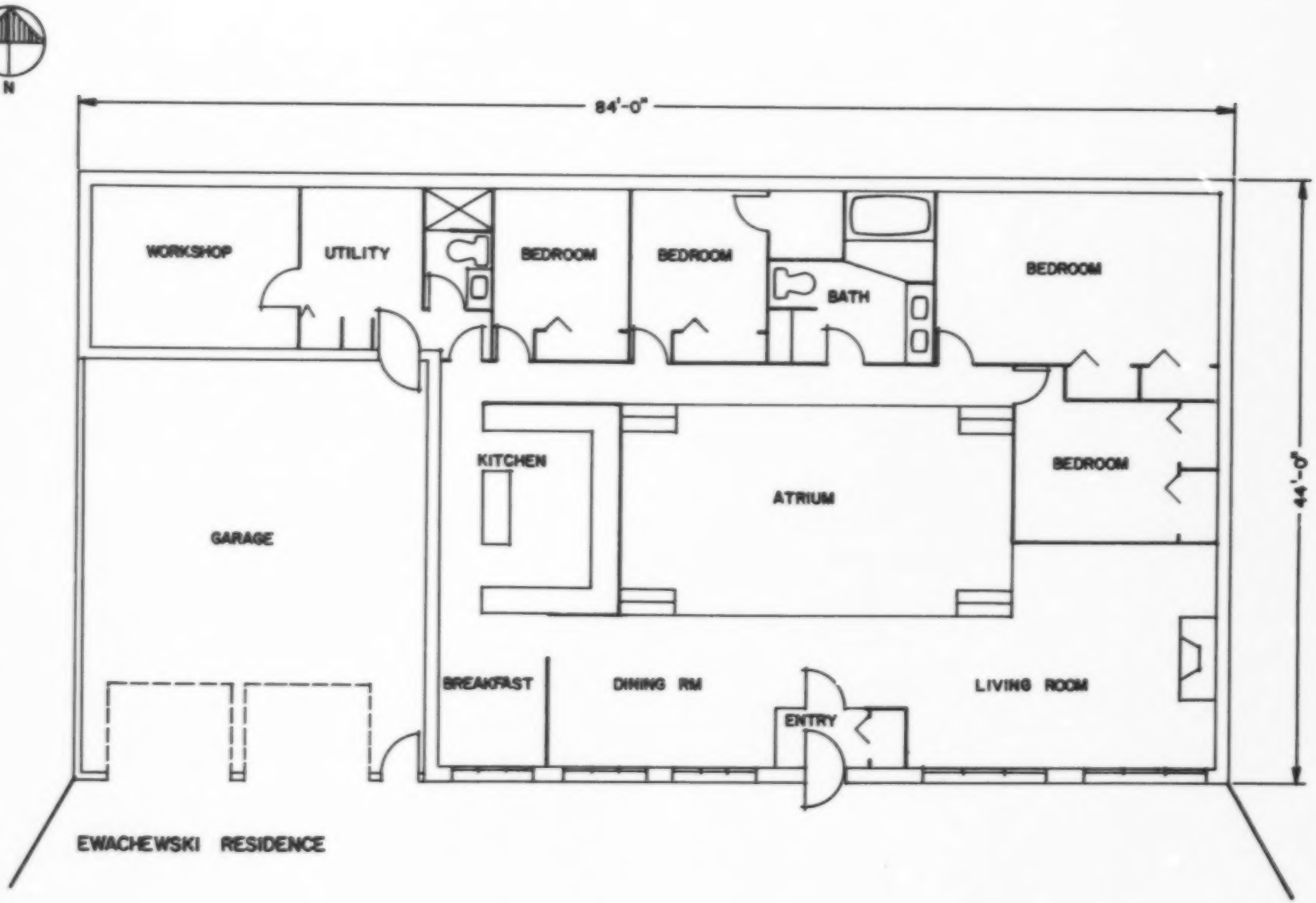
Detail of south window.

Detail of cantilevered floor for walk way along north wall of Atrium.

Detail of interior piping penetrations for future solar system.

APPENDIX G

Floor Plan


N
84'-0"
44'-0"
WORKSHOP
UTILITY
BEDROOM
BEDROOM
BATH
BEDROOM
KITCHEN
ATRIUM
BEDROOM
GARAGE
BREAKFAST
DINING RM
LIVING ROOM
ENTRY
EWACHEWSKI RESIDENCE

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